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Uchibori

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(54) **ENGINE DEVICE**

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patent is extended or adjusted under 35
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application No. PCT/JP2017/012963 on Mar. 29,
2017, now Pat. No. 10,781,743.

(30) **Foreign Application Priority Data**

Apr. 8, 2016 (JP) JP2016-078467

(51) **Int. Cl.**

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F02B 37/18 (2006.01)
F01M 13/00 (2006.01)
F02B 37/00 (2006.01)
F02B 37/02 (2006.01)
F02M 35/10 (2006.01)

(52) **U.S. Cl.**

CPC **F02B 37/013** (2013.01); **F01M 13/00**
(2013.01); **F02B 37/00** (2013.01); **F02B 37/02**
(2013.01); **F02B 37/18** (2013.01); **F02M**
35/10157 (2013.01); **Y02T 10/12** (2013.01)

(58) **Field of Classification Search**

CPC F01M 13/00; F02B 37/00; F02B 37/013;
F02B 37/02; F02B 37/18; F02M
35/10157; Y02T 10/144

See application file for complete search history.

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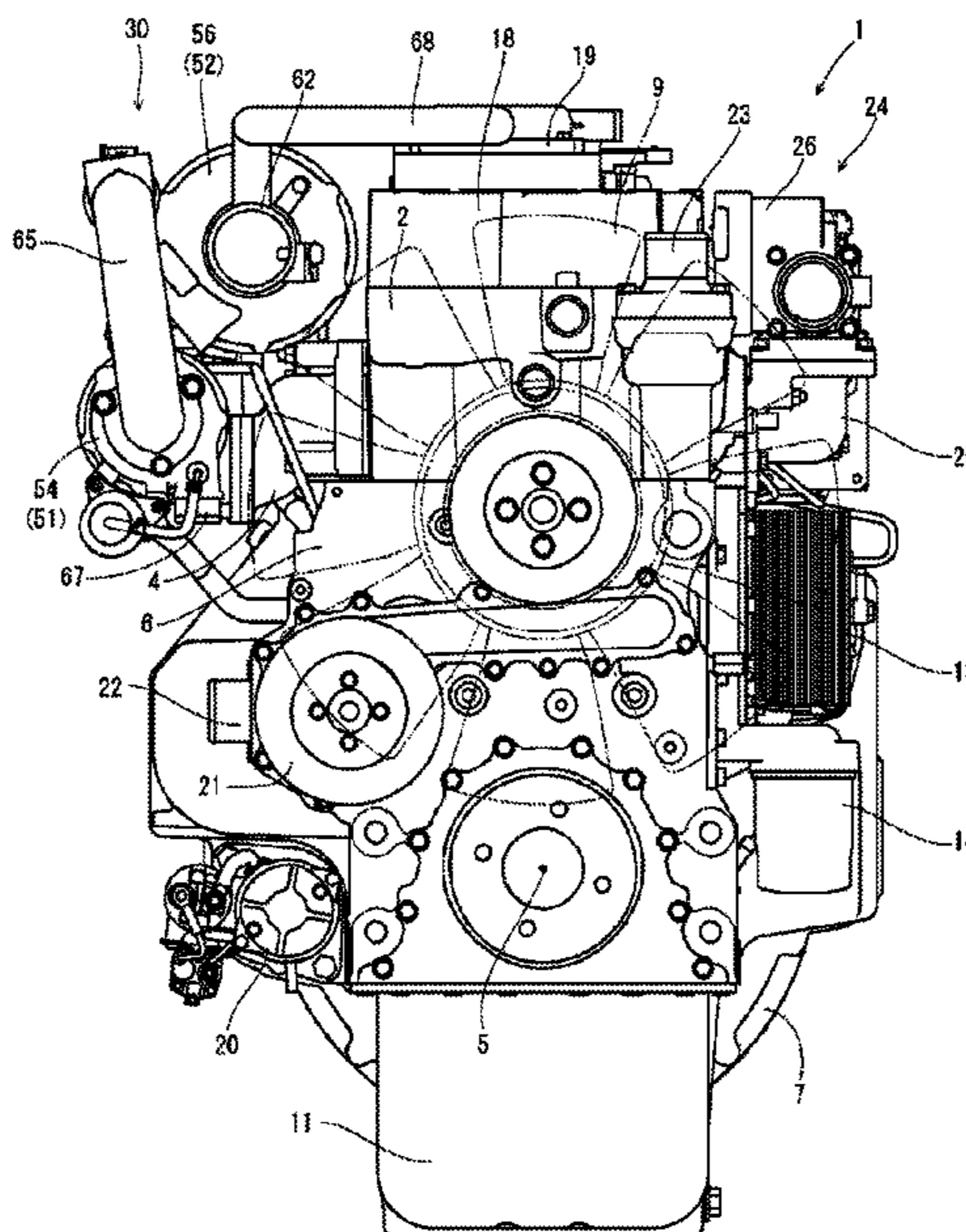
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(74) *Attorney, Agent, or Firm* — Chris Mizumoto

(57) **ABSTRACT**

An engine device 1 includes: an exhaust manifold 4 dis-
posed on one of left and right sides of a cylinder head 2,
and an intake manifold 3 disposed on the other of the left and
right sides of the cylinder head 2; and a turbocharger 30 that
uses fluid energy of an exhaust gas discharged from the
exhaust manifold 4, to compress fresh air to be flowed into
the intake manifold 3. The turbocharger 30 is constituted by
a two-stage turbocharger including a high-pressure turbo-
charger 51 coupled to the exhaust manifold 4 and a low-
pressure turbocharger 52 coupled to the high-pressure tur-
bocharger 51. The high-pressure turbocharger 51 is disposed
on one of left and right lateral sides of the exhaust manifold
4, while the low-pressure turbocharger 52 is disposed above
the exhaust manifold 4.

6 Claims, 29 Drawing Sheets



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FIG. 1

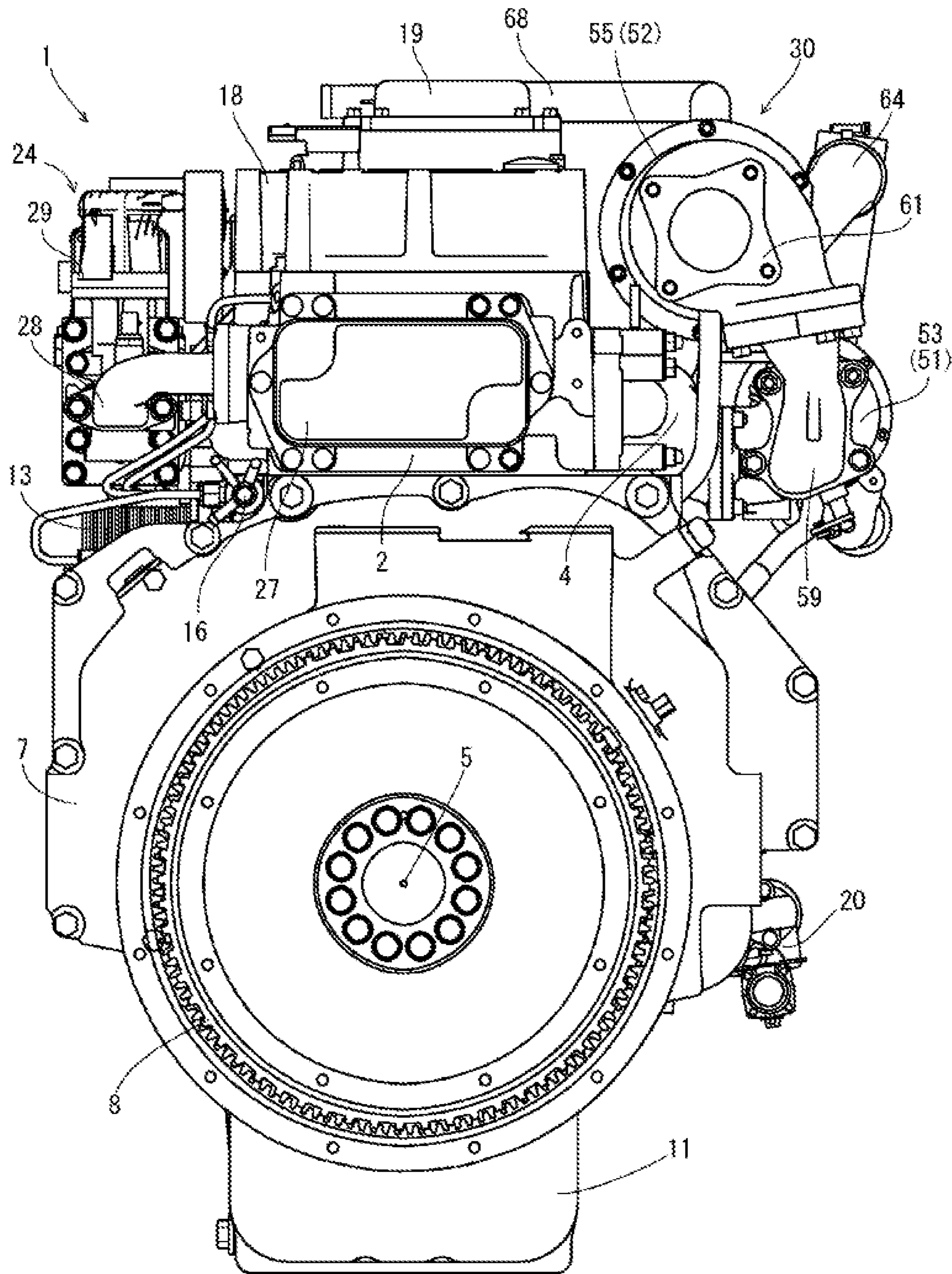


FIG. 2

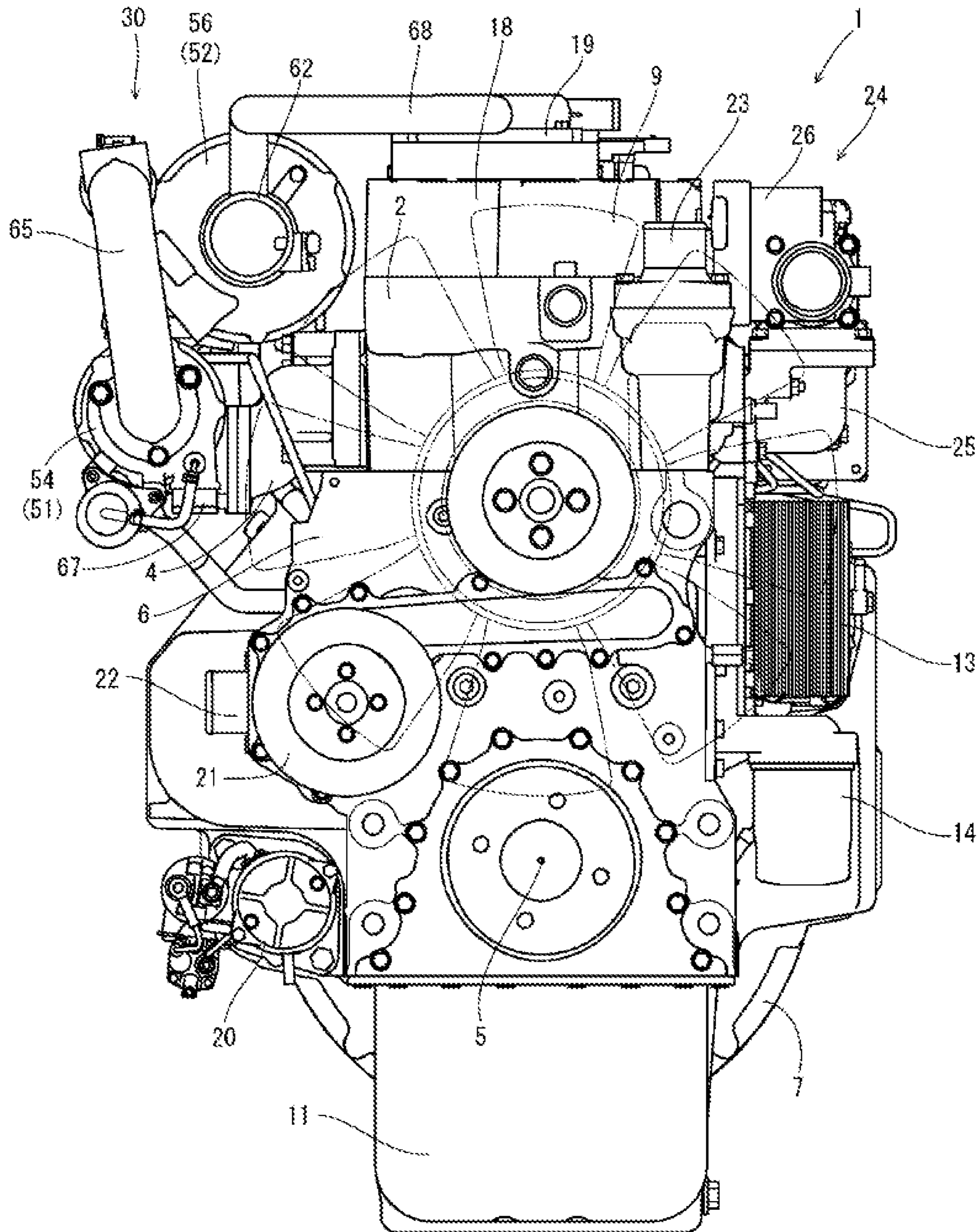


FIG. 3

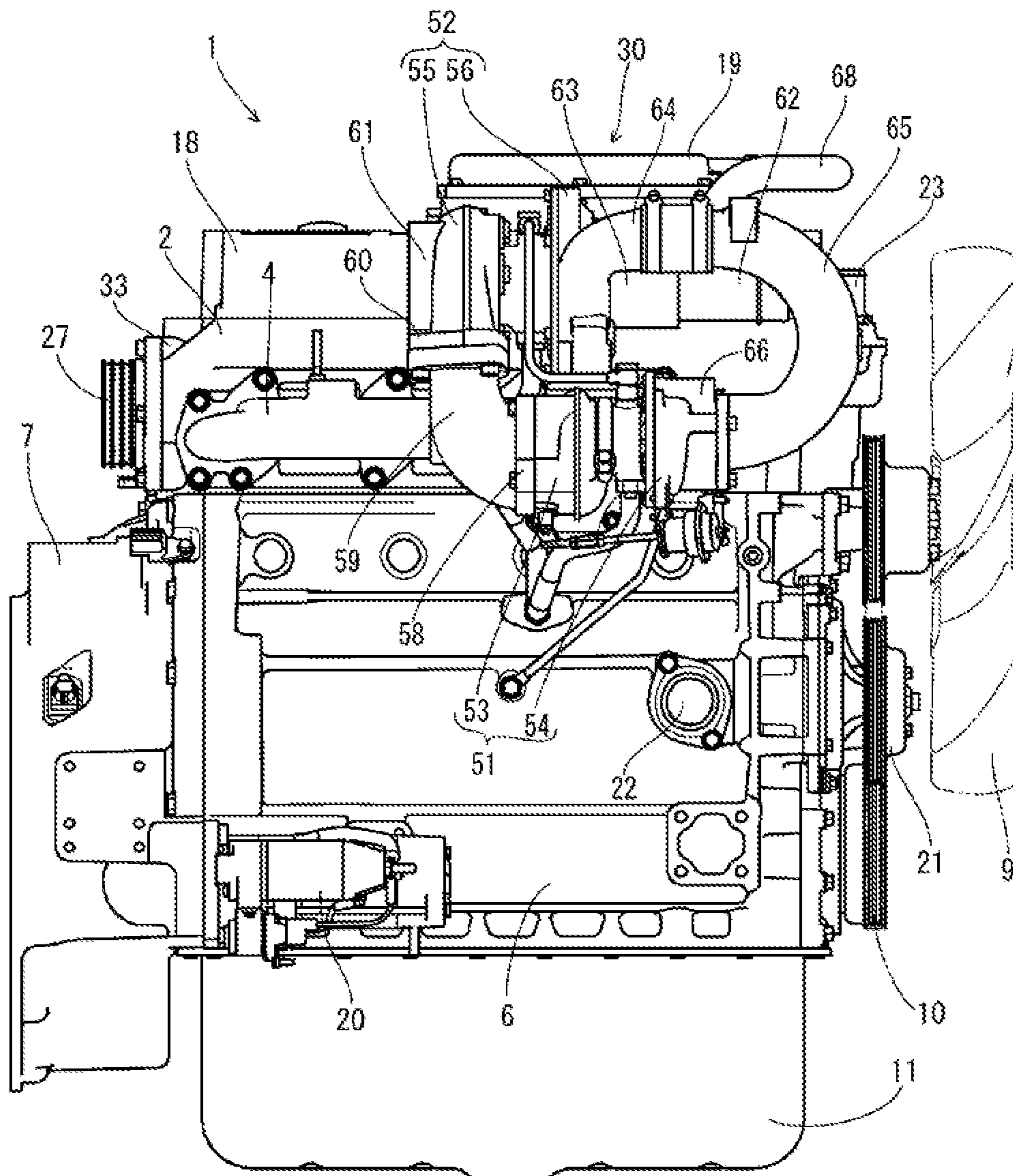


FIG. 4

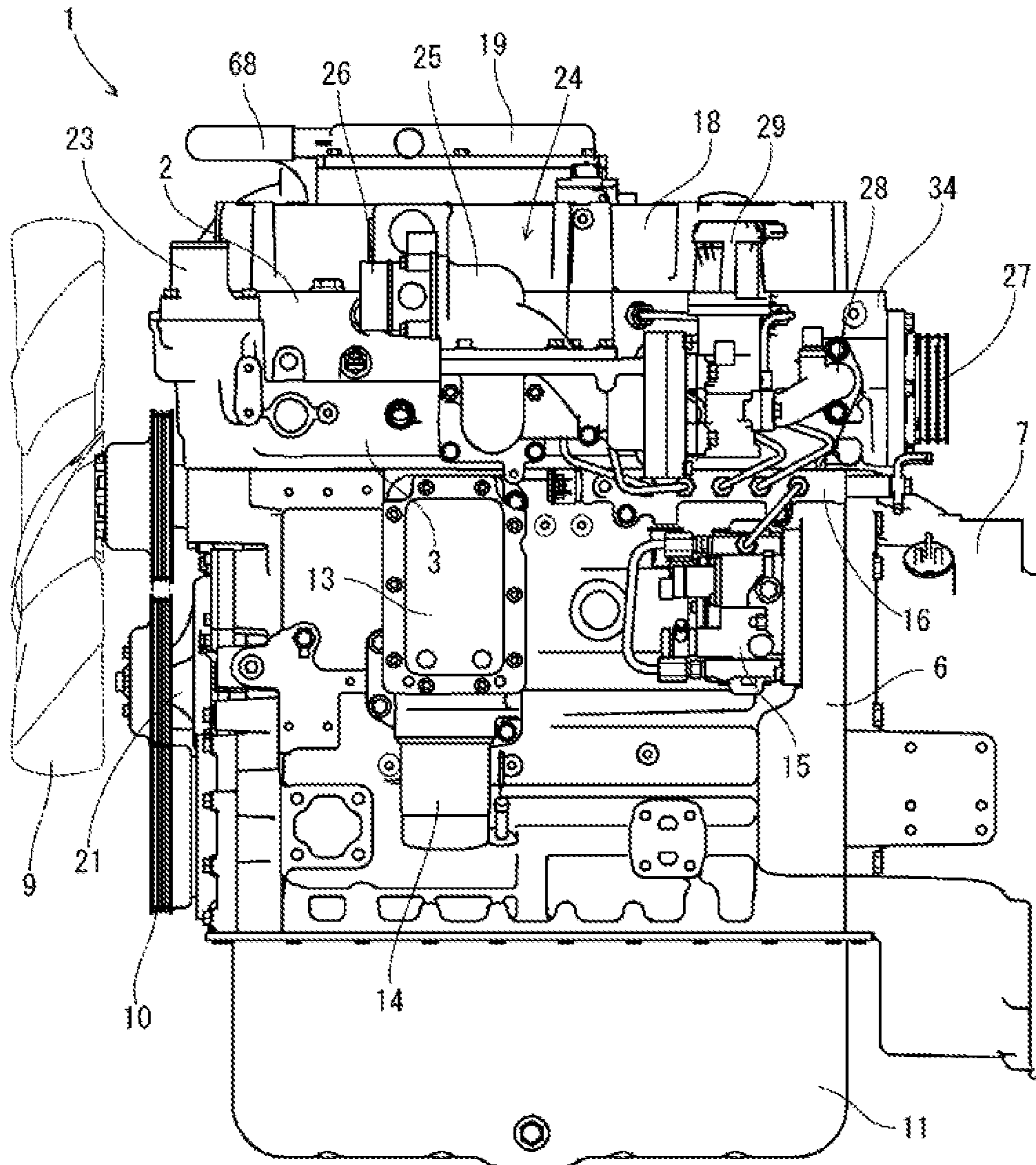


FIG. 5

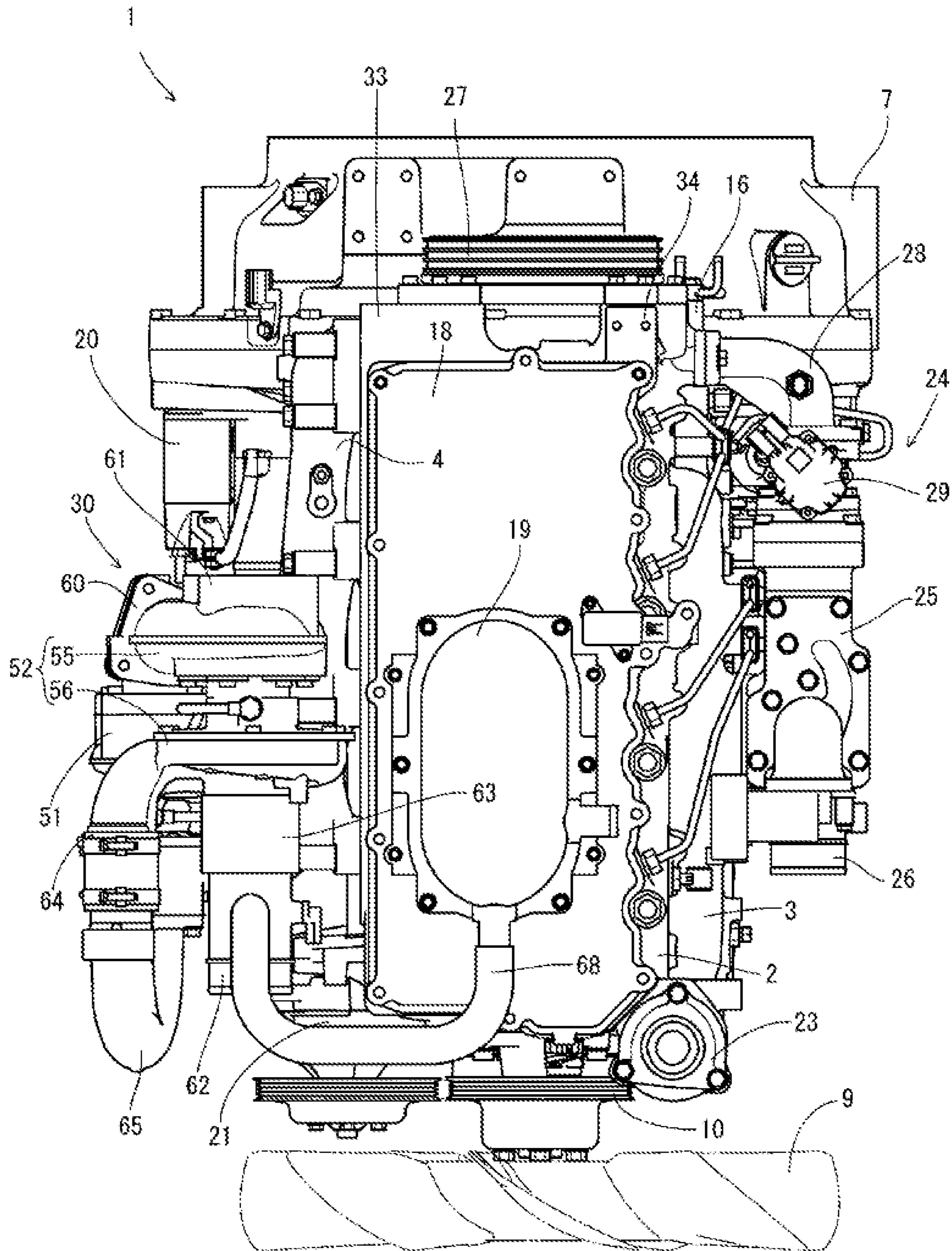


FIG. 6

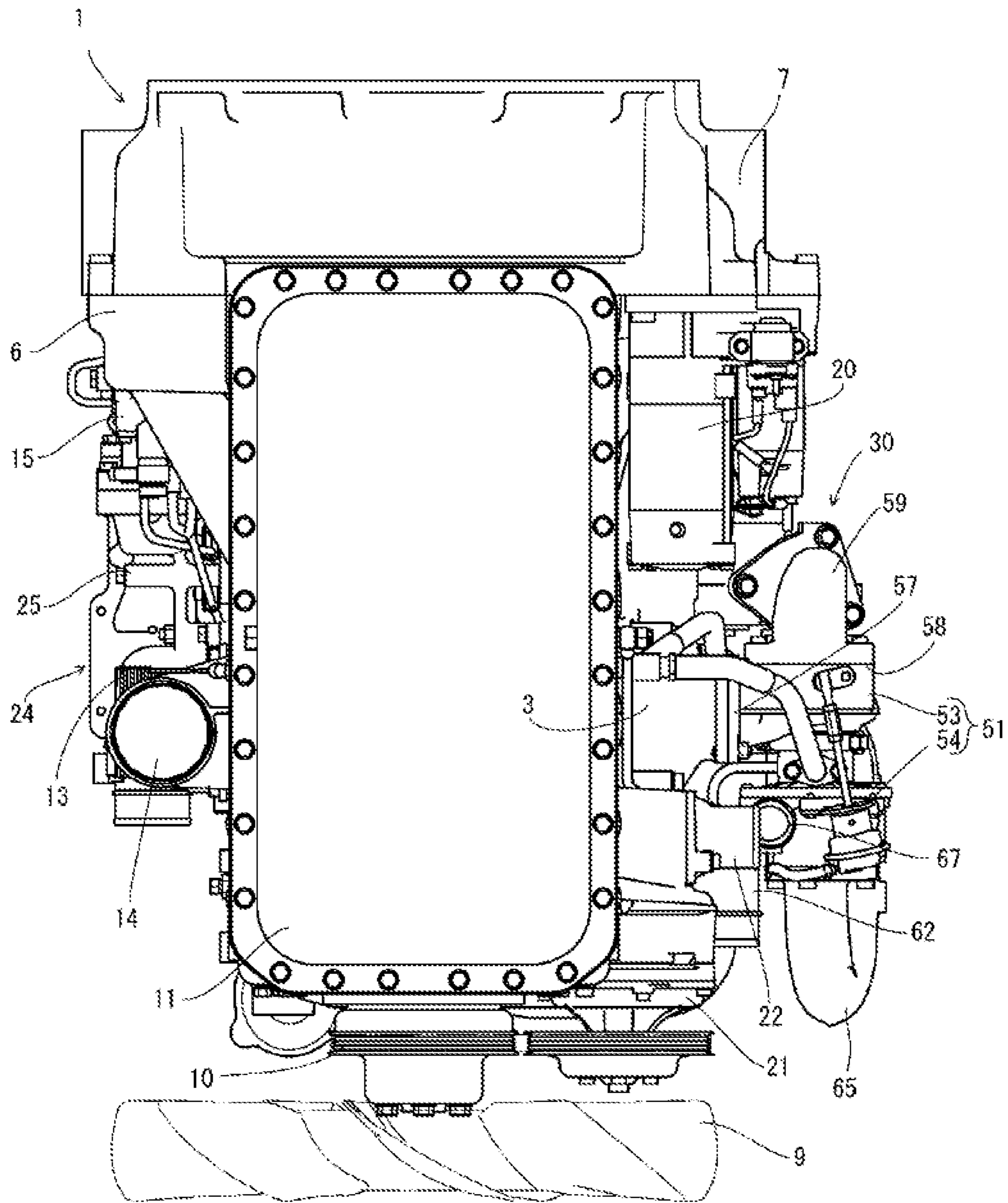


FIG. 7

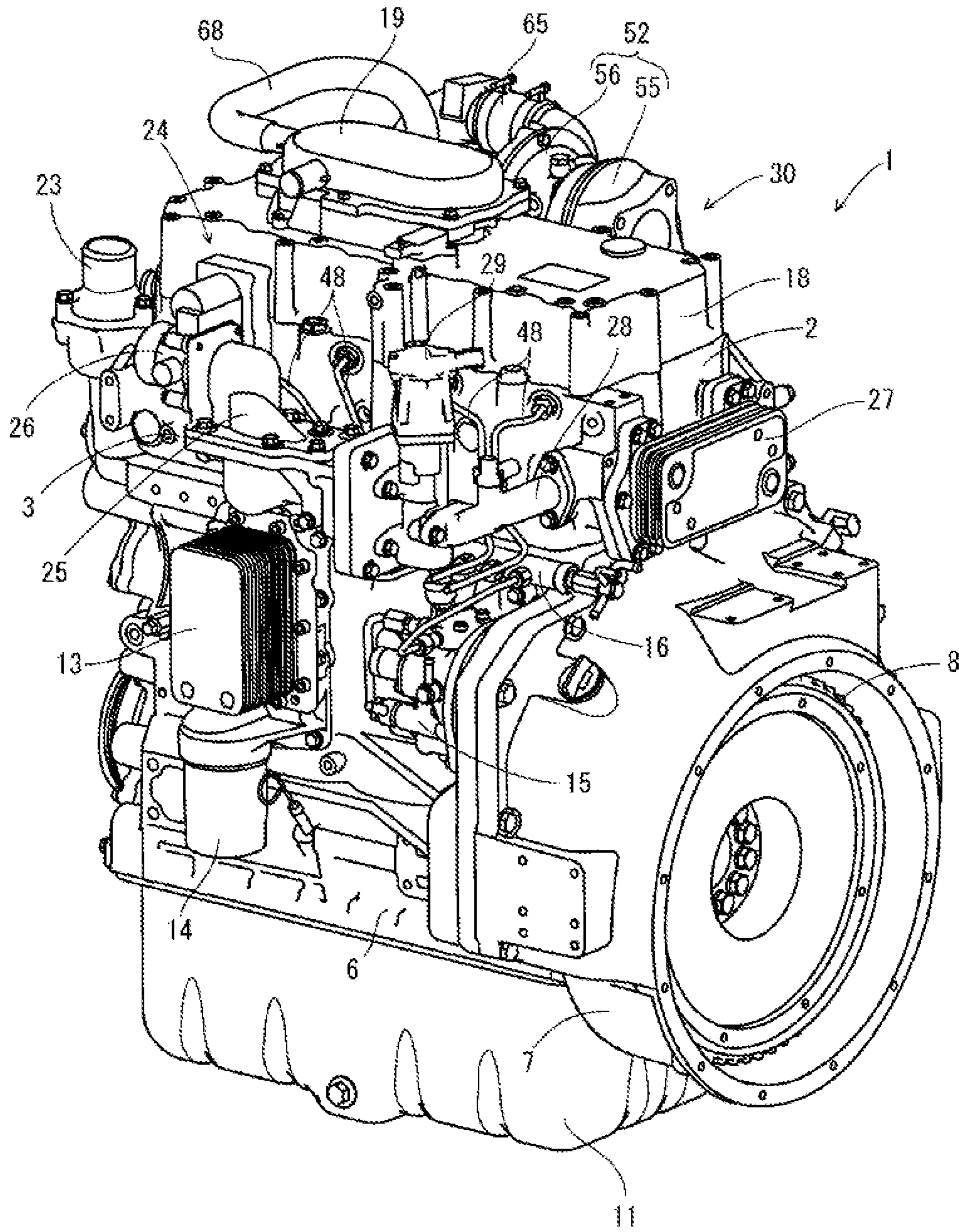


FIG. 8

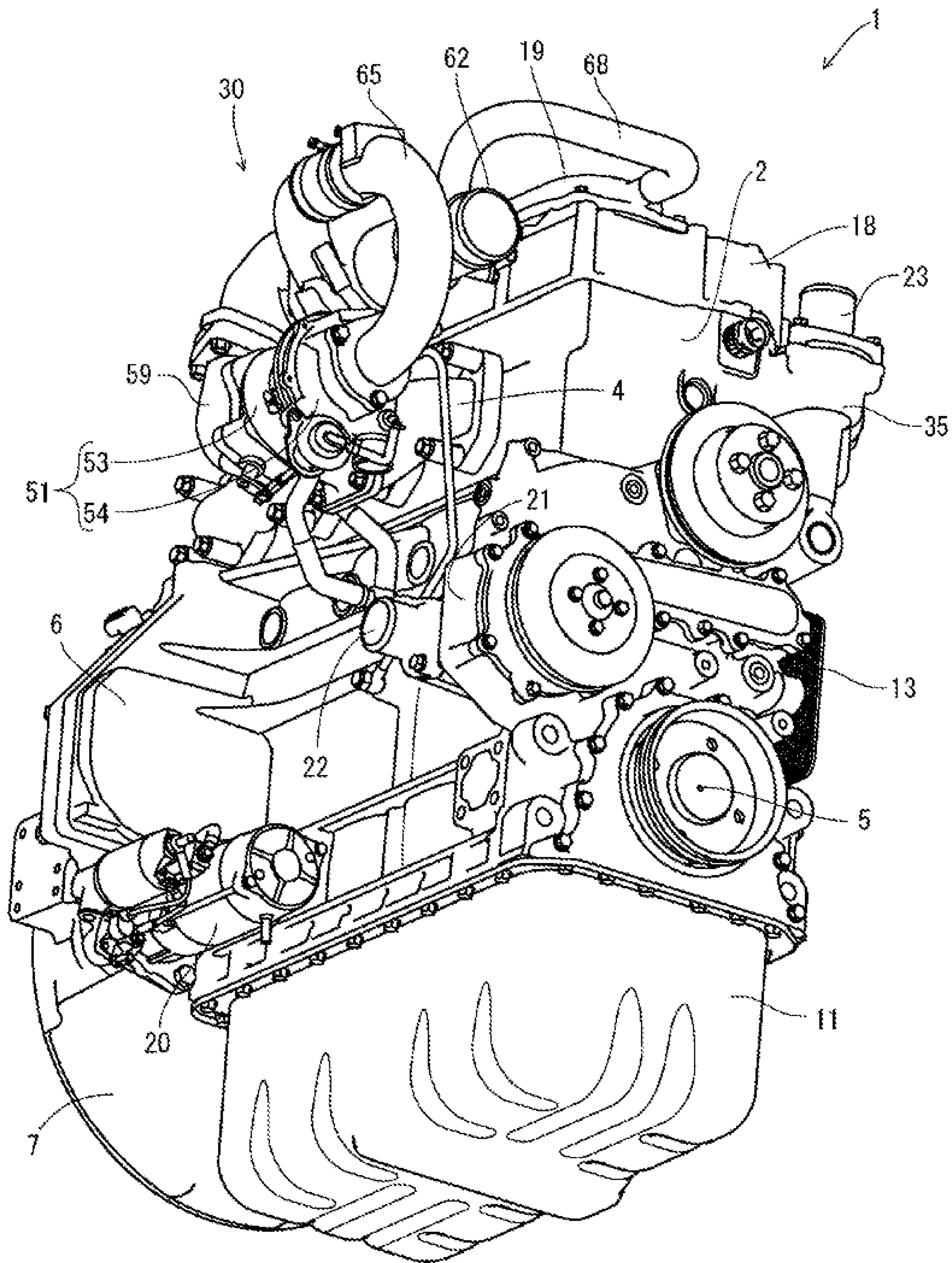


FIG. 9

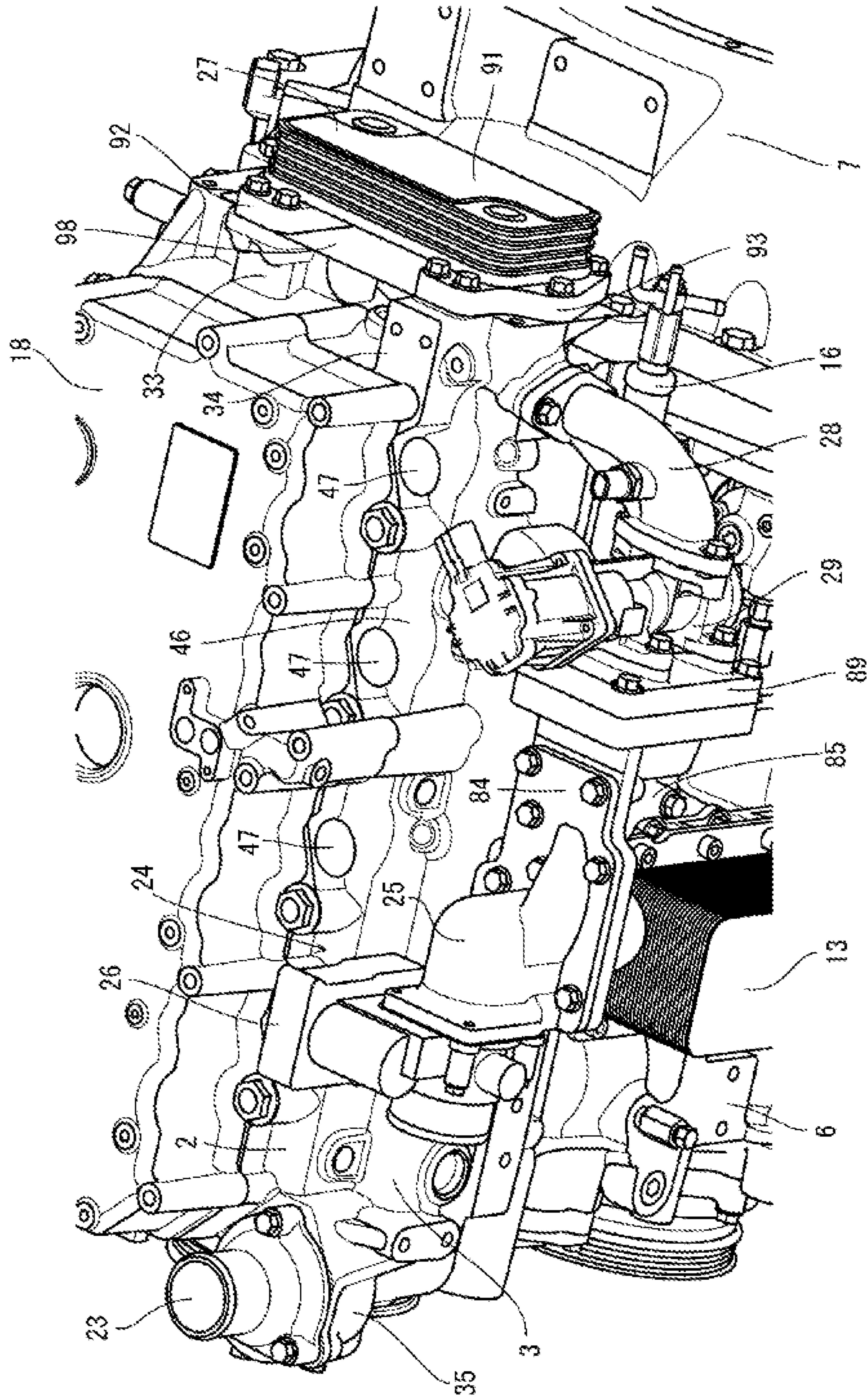


FIG. 10

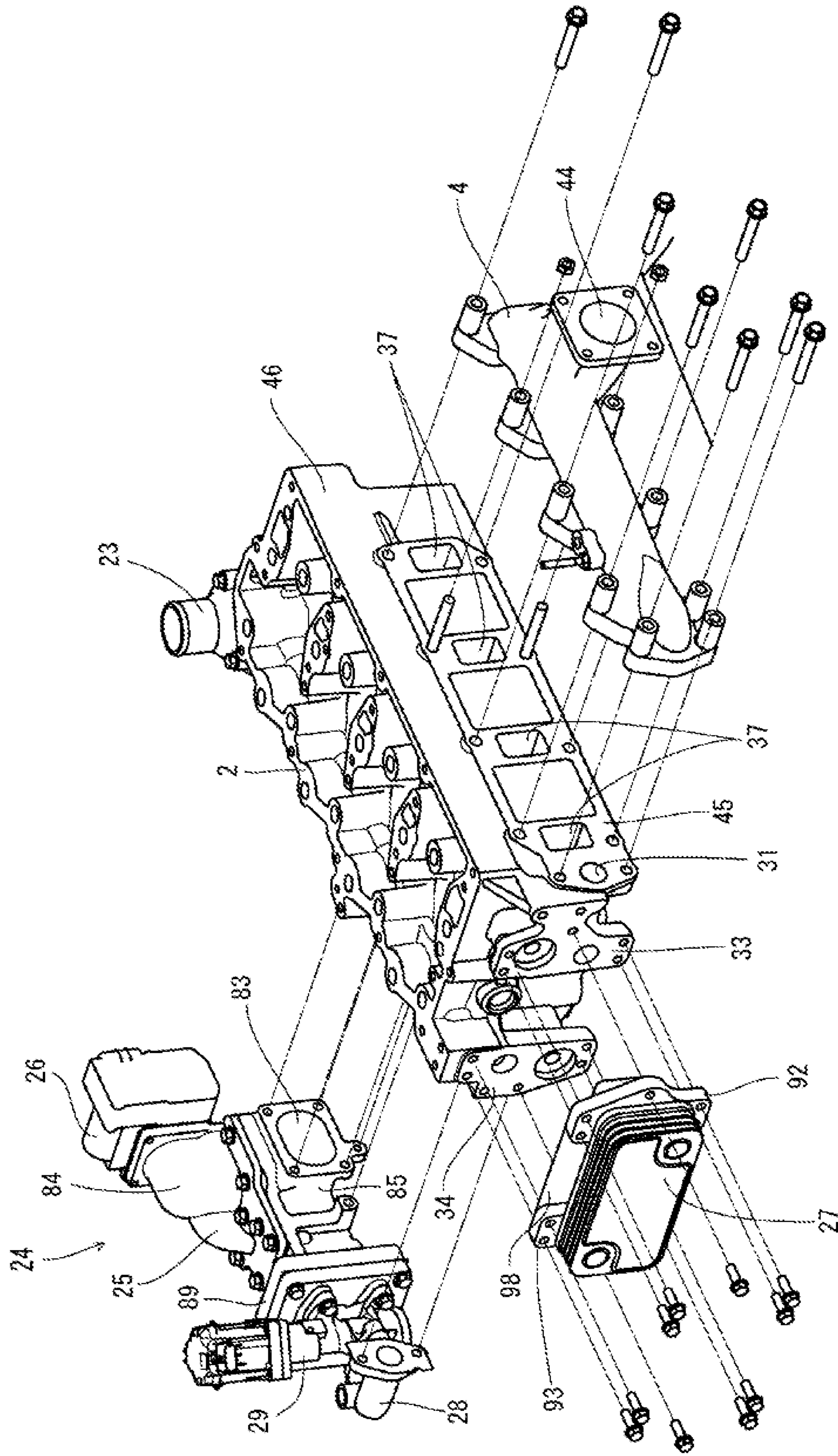


FIG. 11

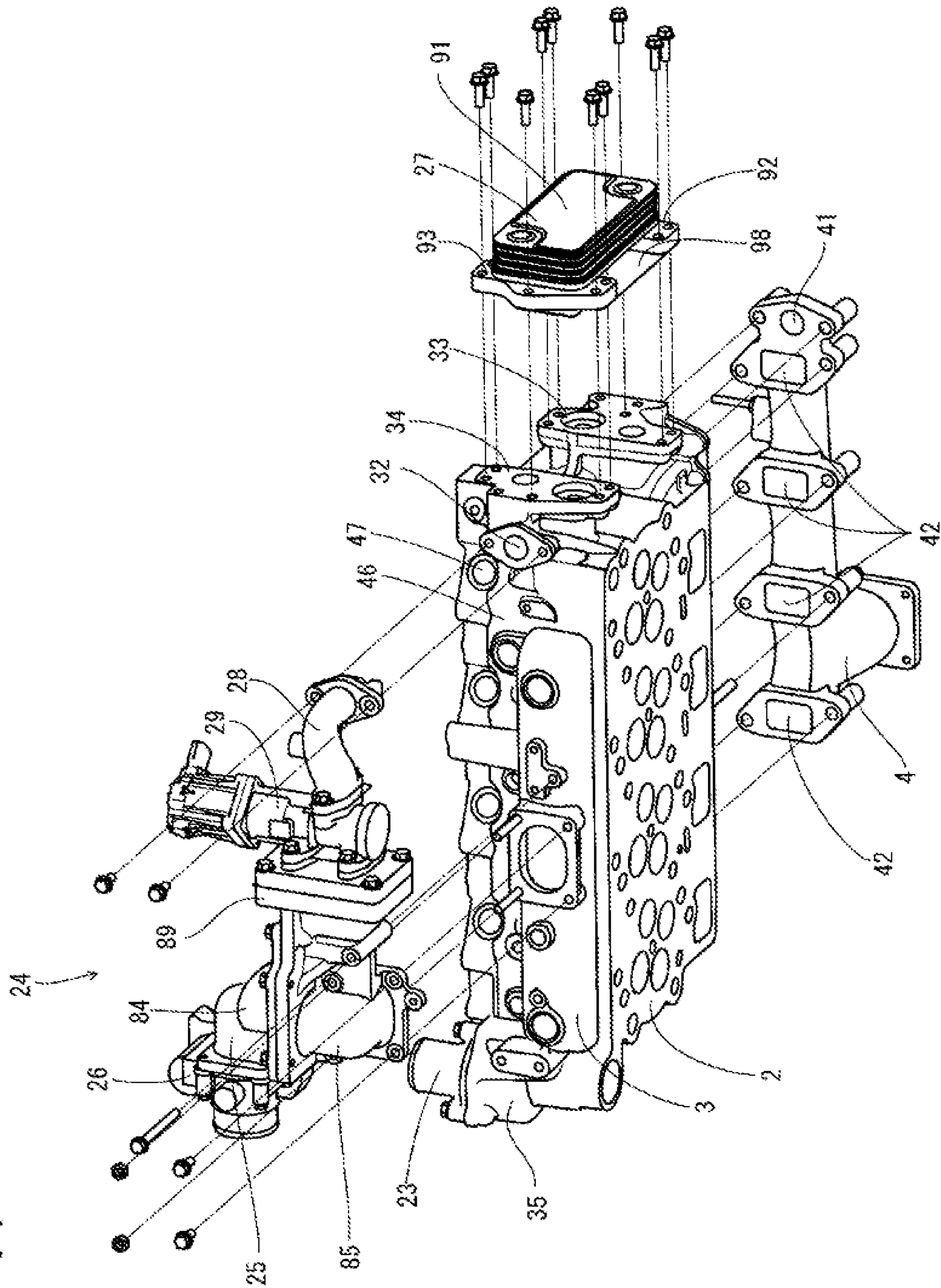


FIG. 12

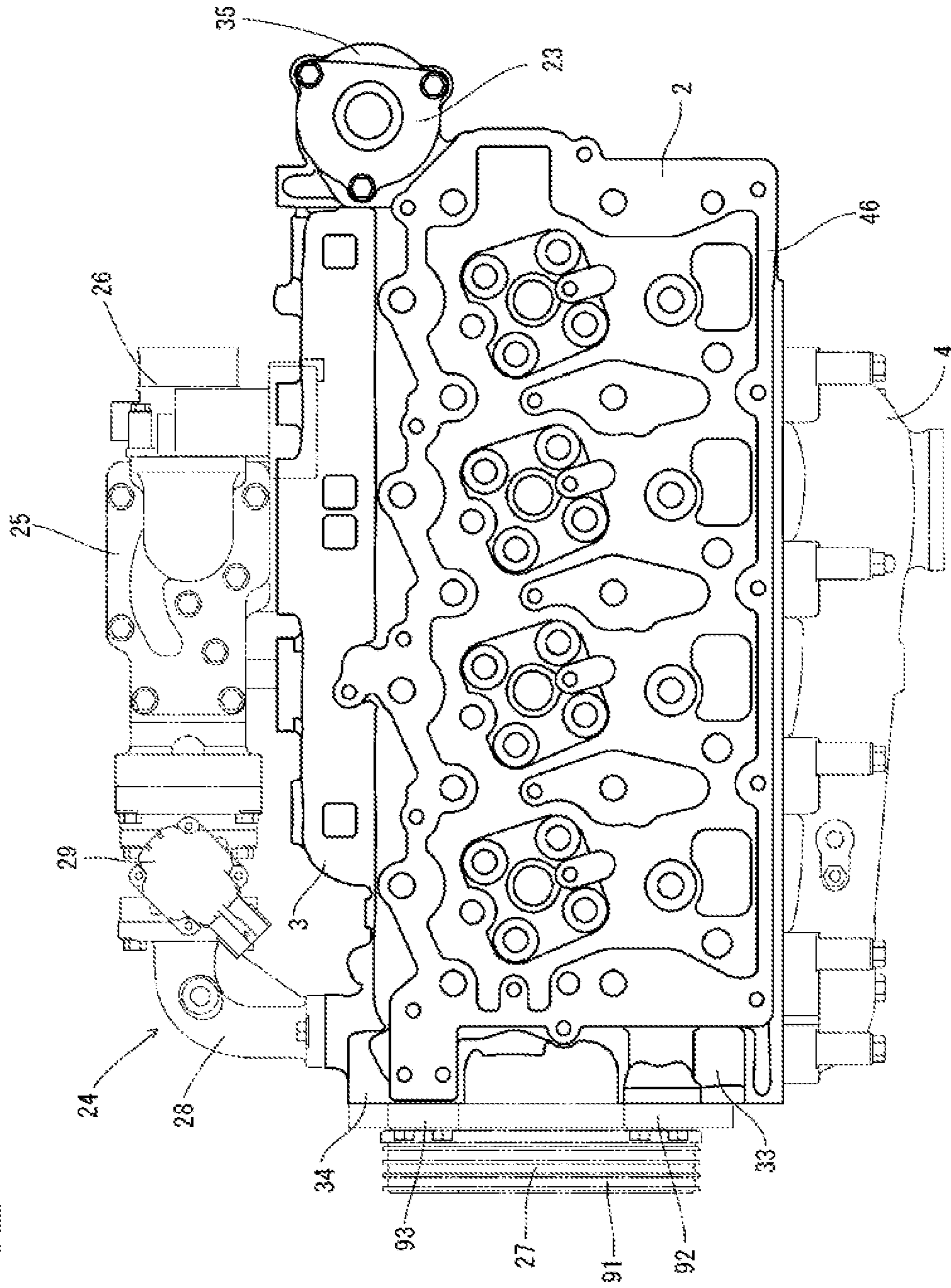


FIG. 13

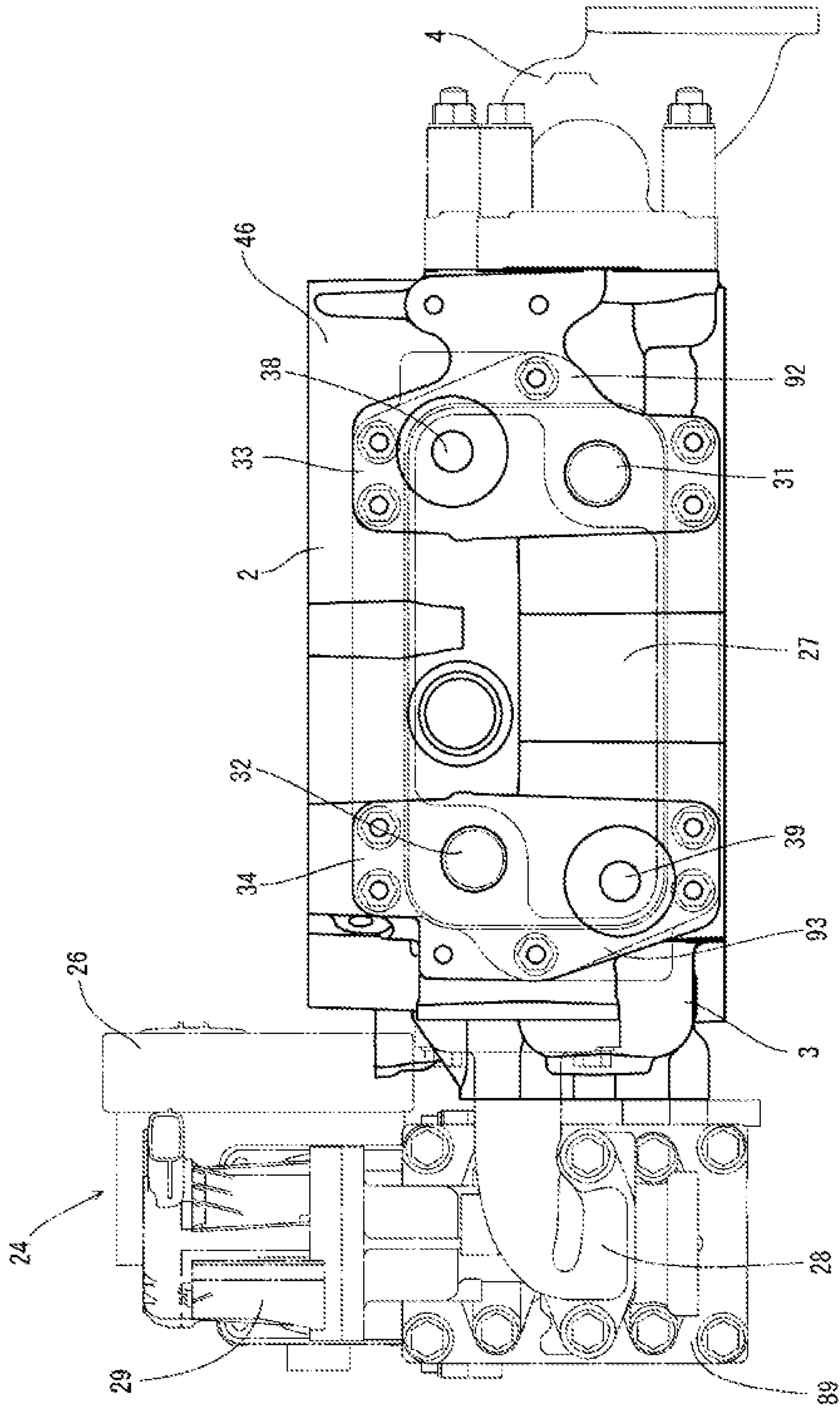
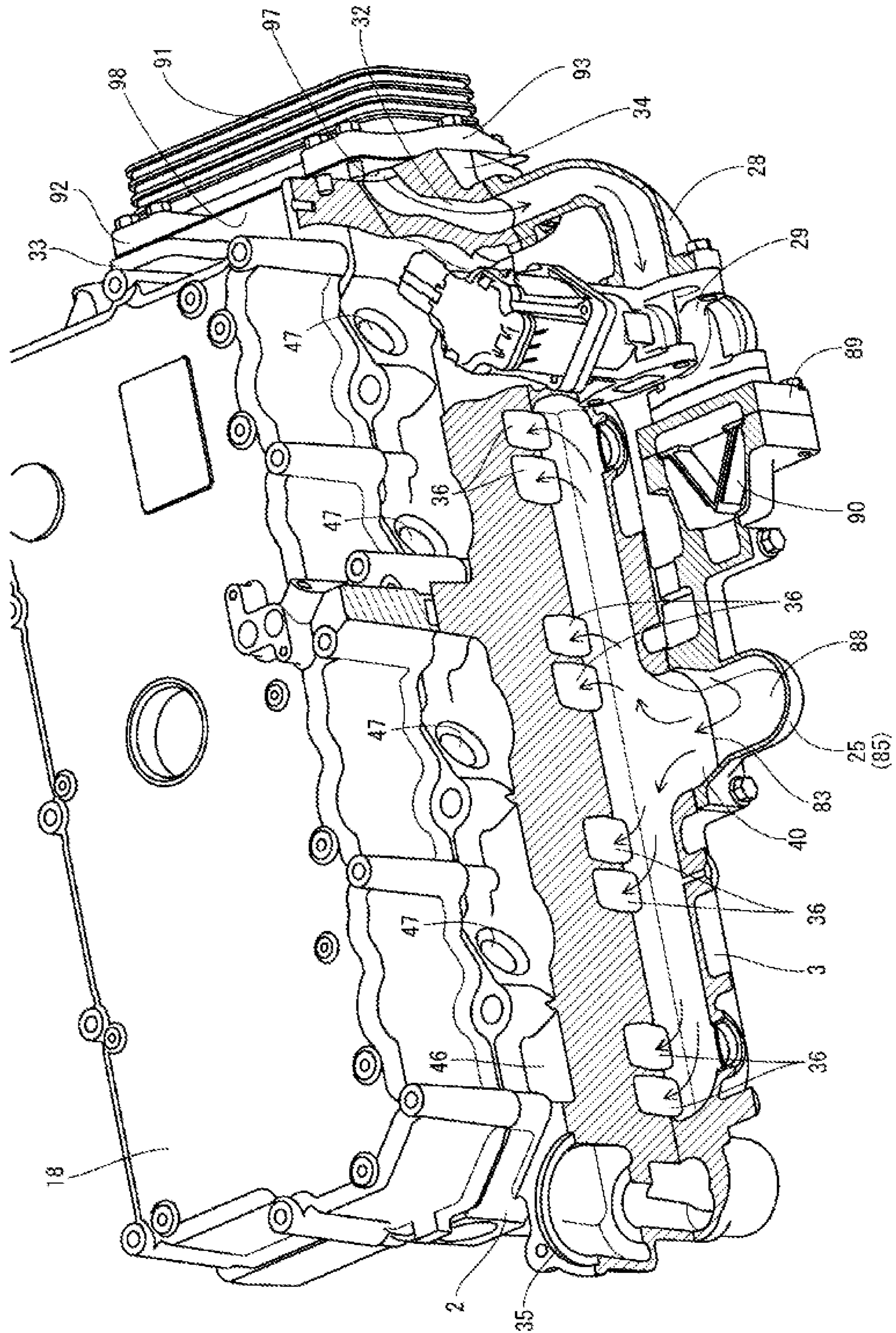


FIG. 14



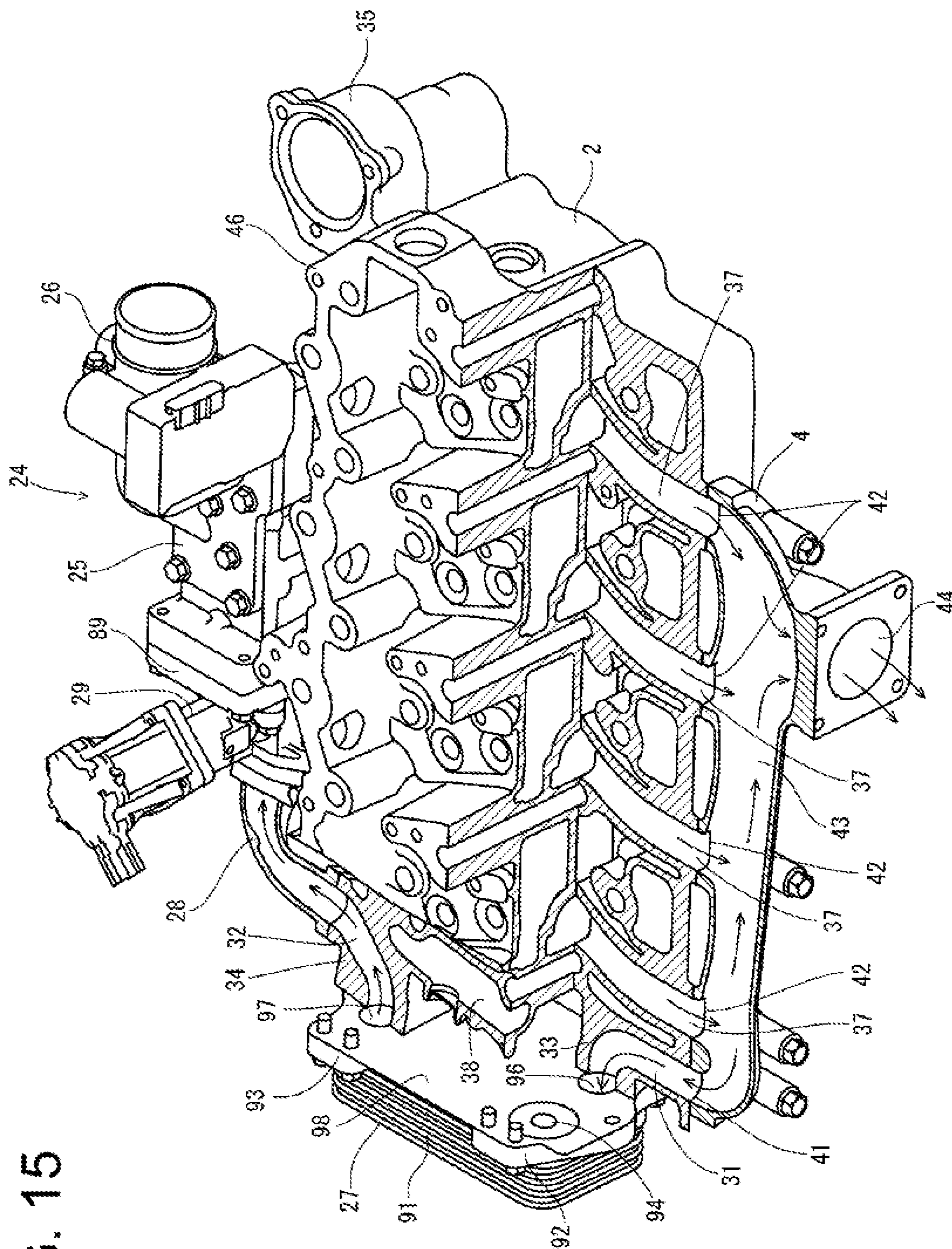


FIG. 15

FIG. 16

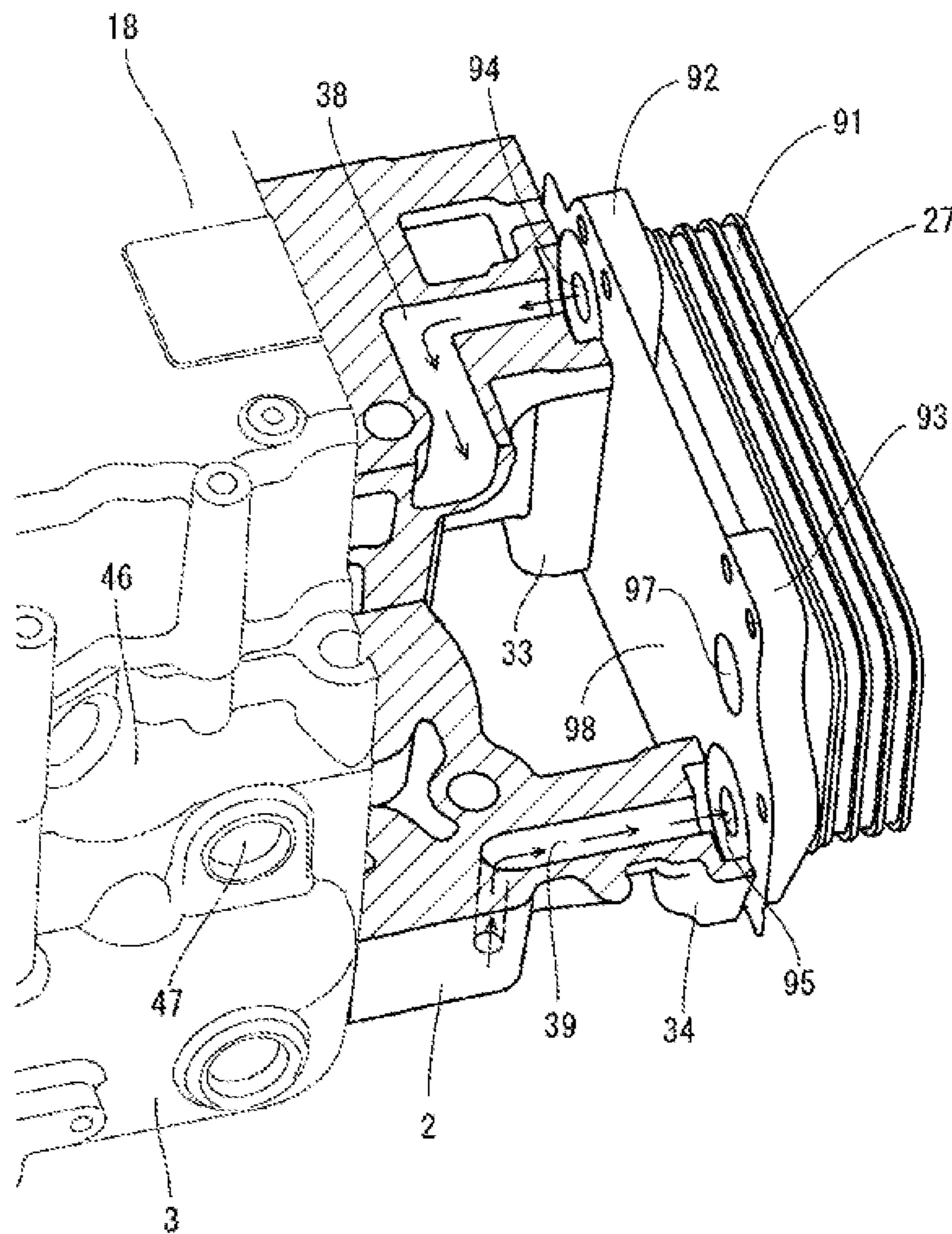


FIG. 17

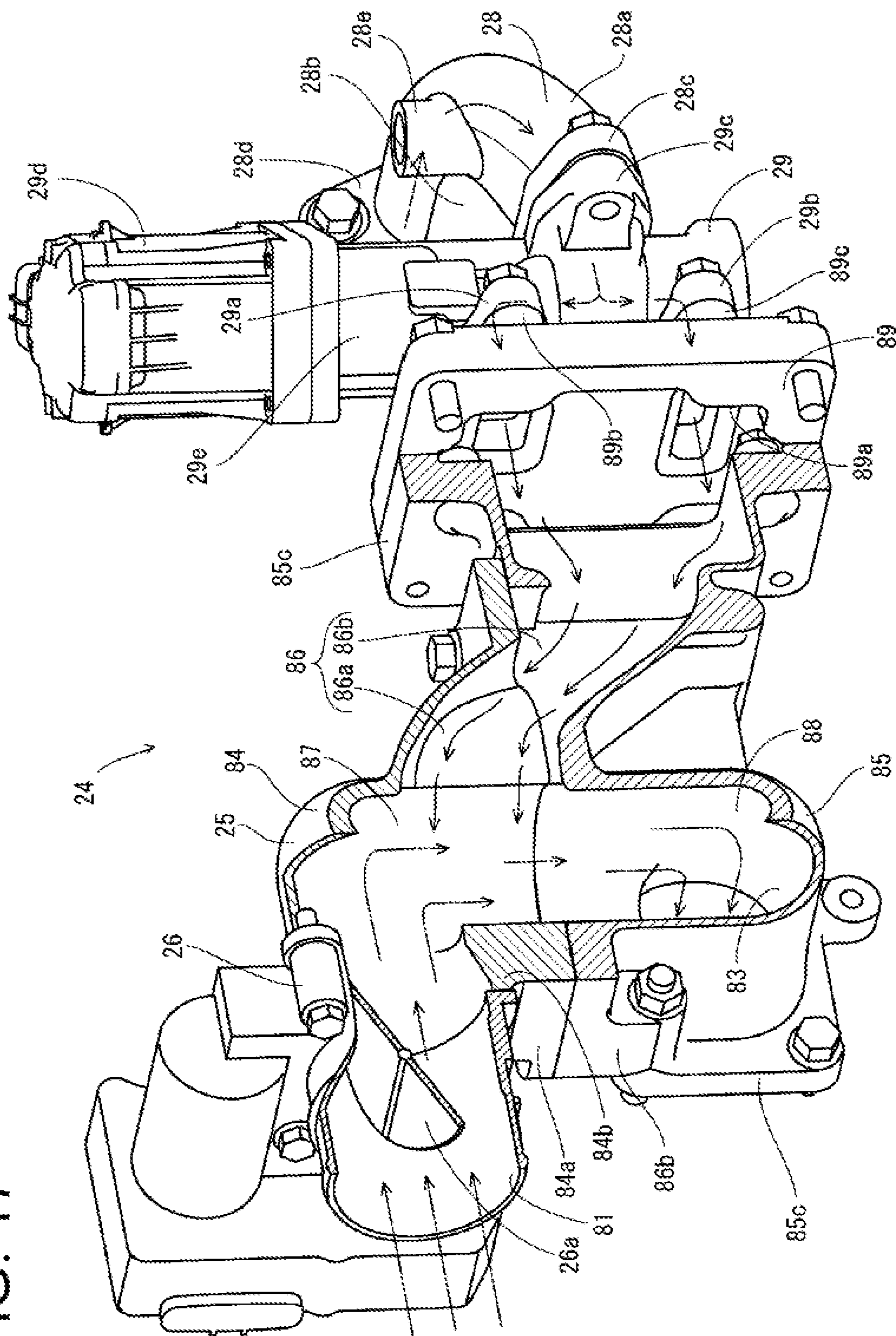


FIG. 18

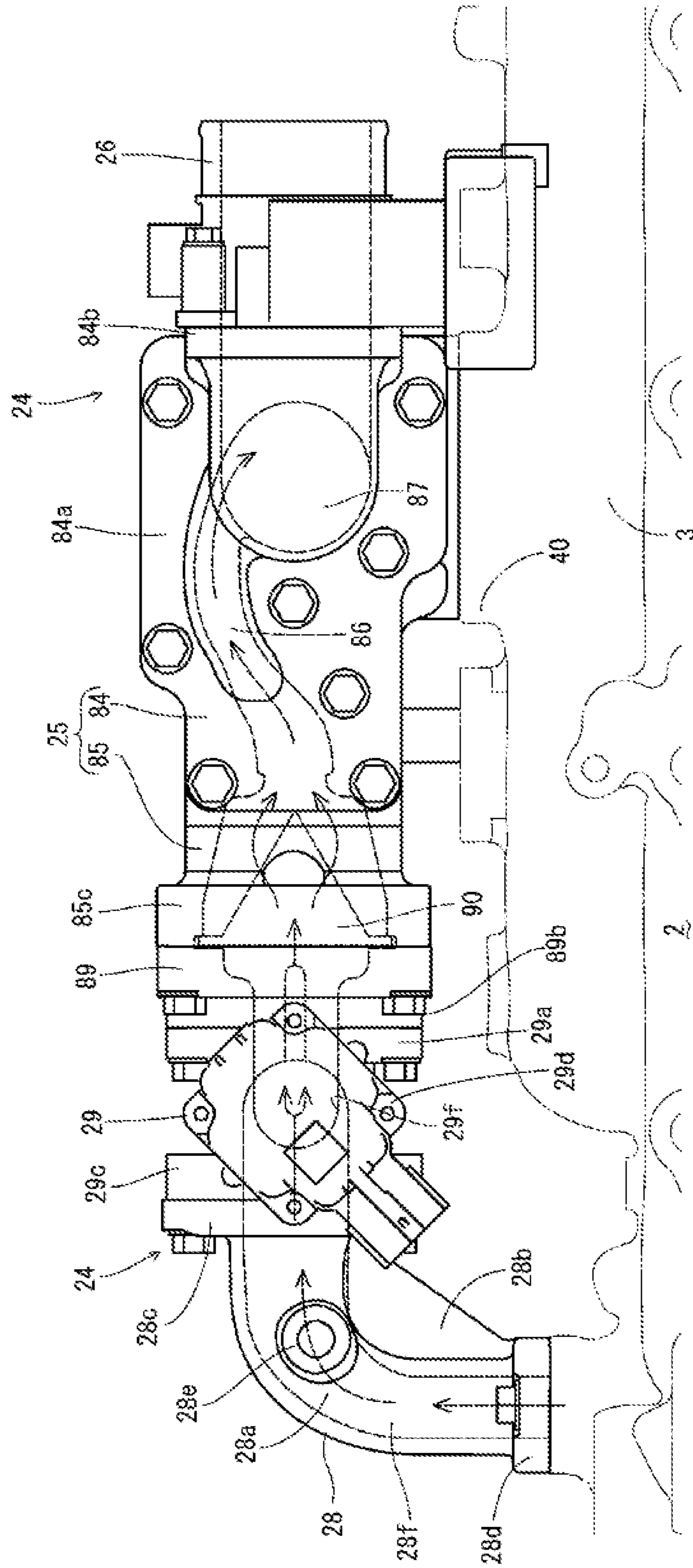


FIG. 20

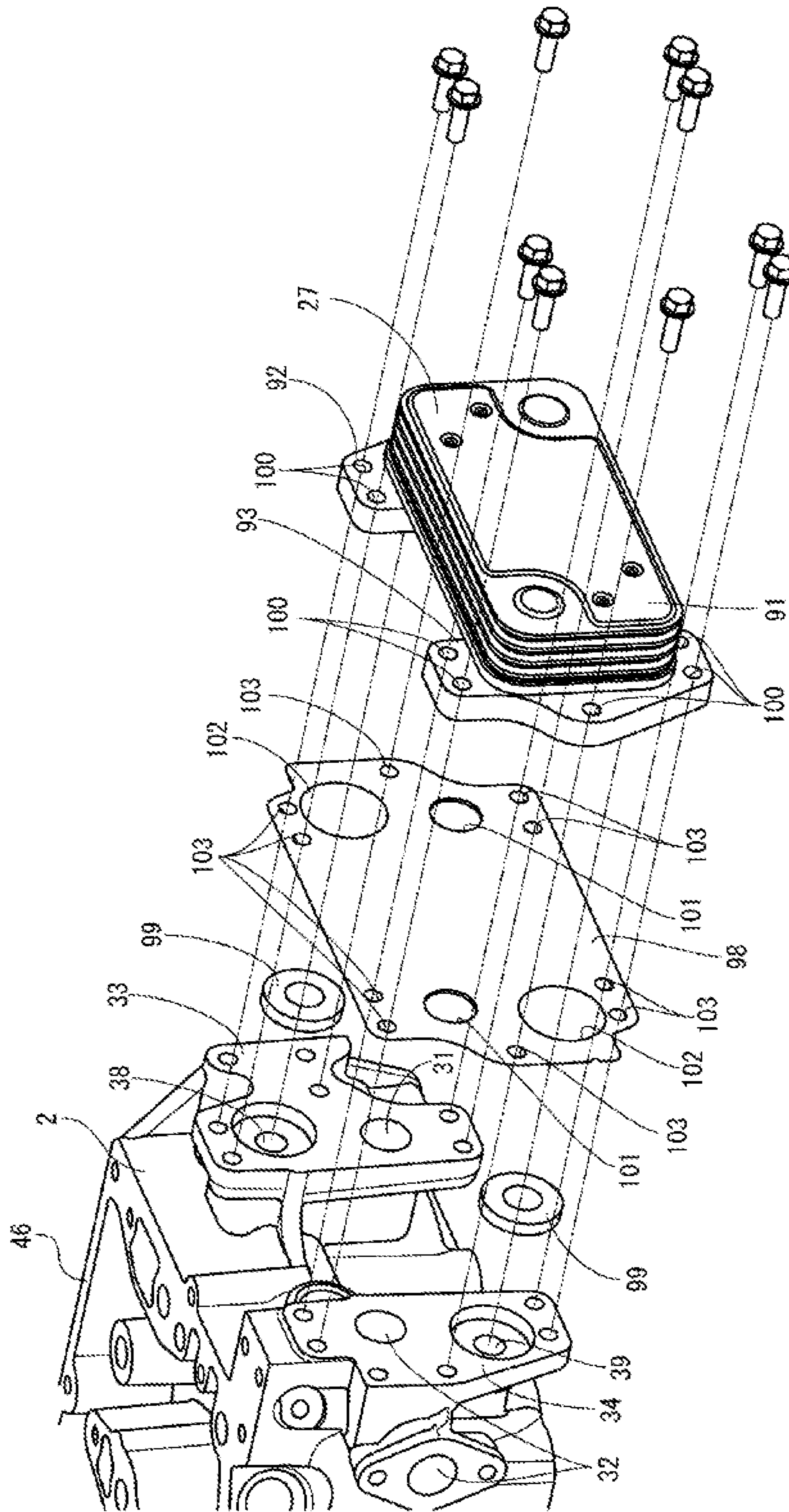


FIG. 21

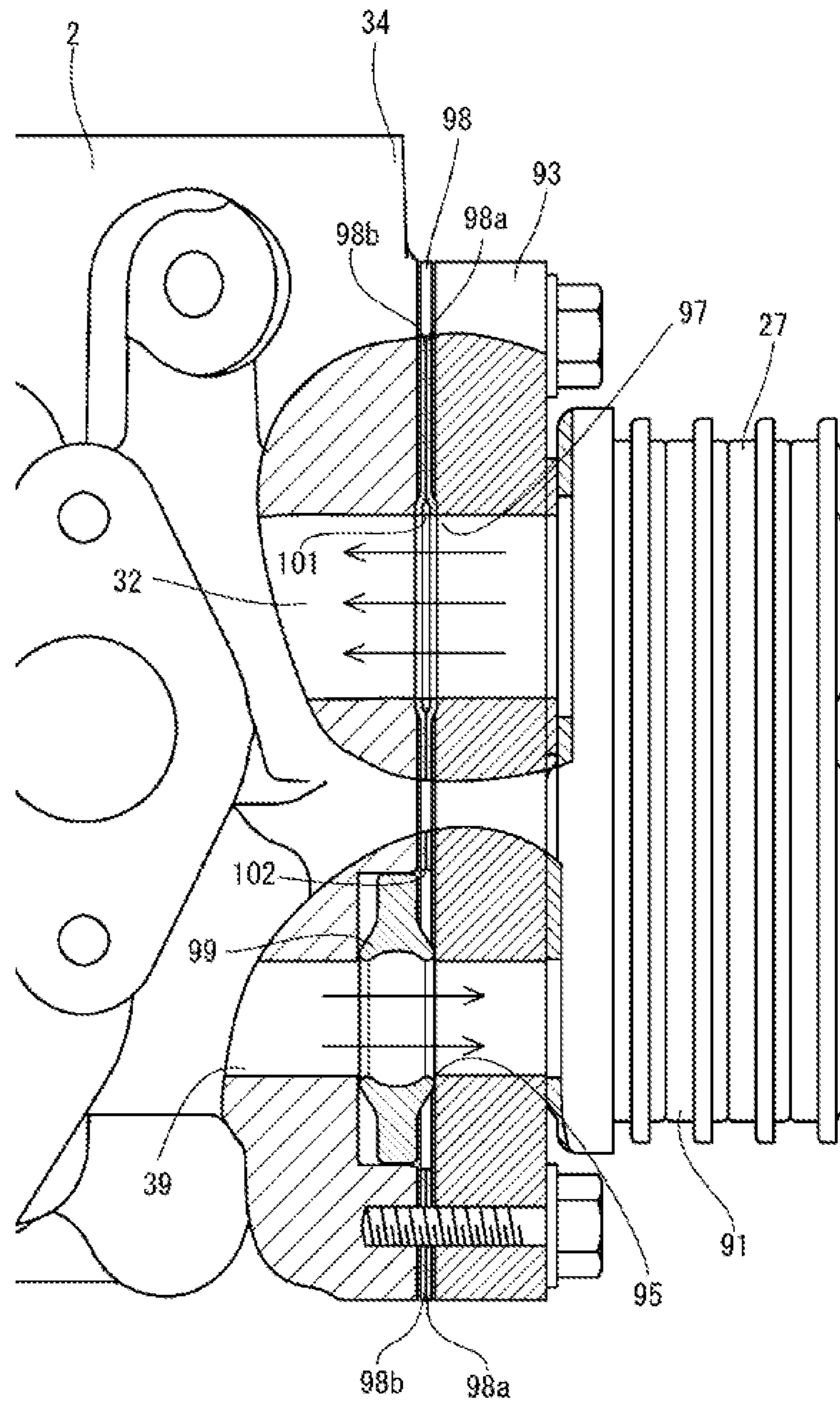


FIG. 22

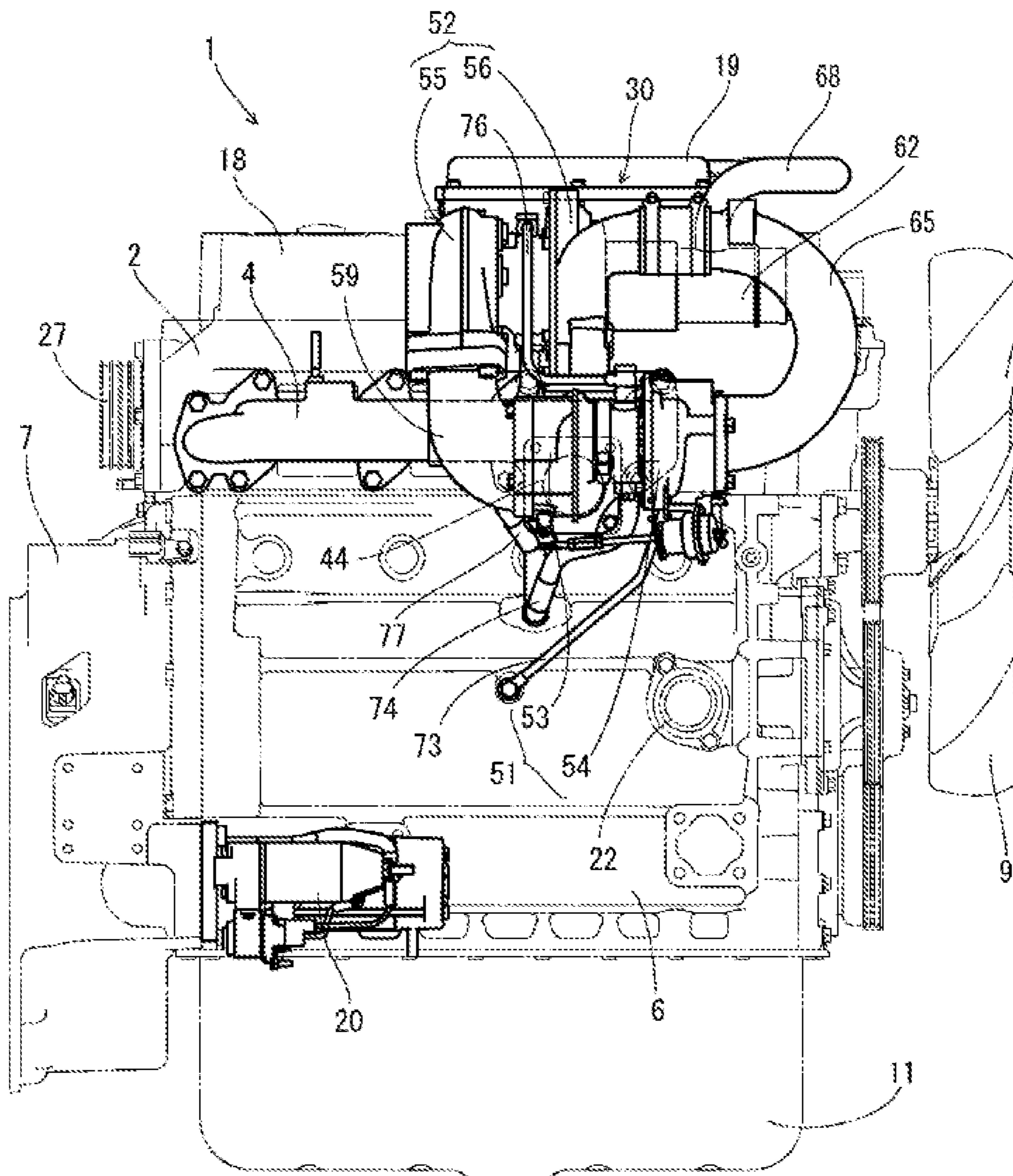


FIG. 23

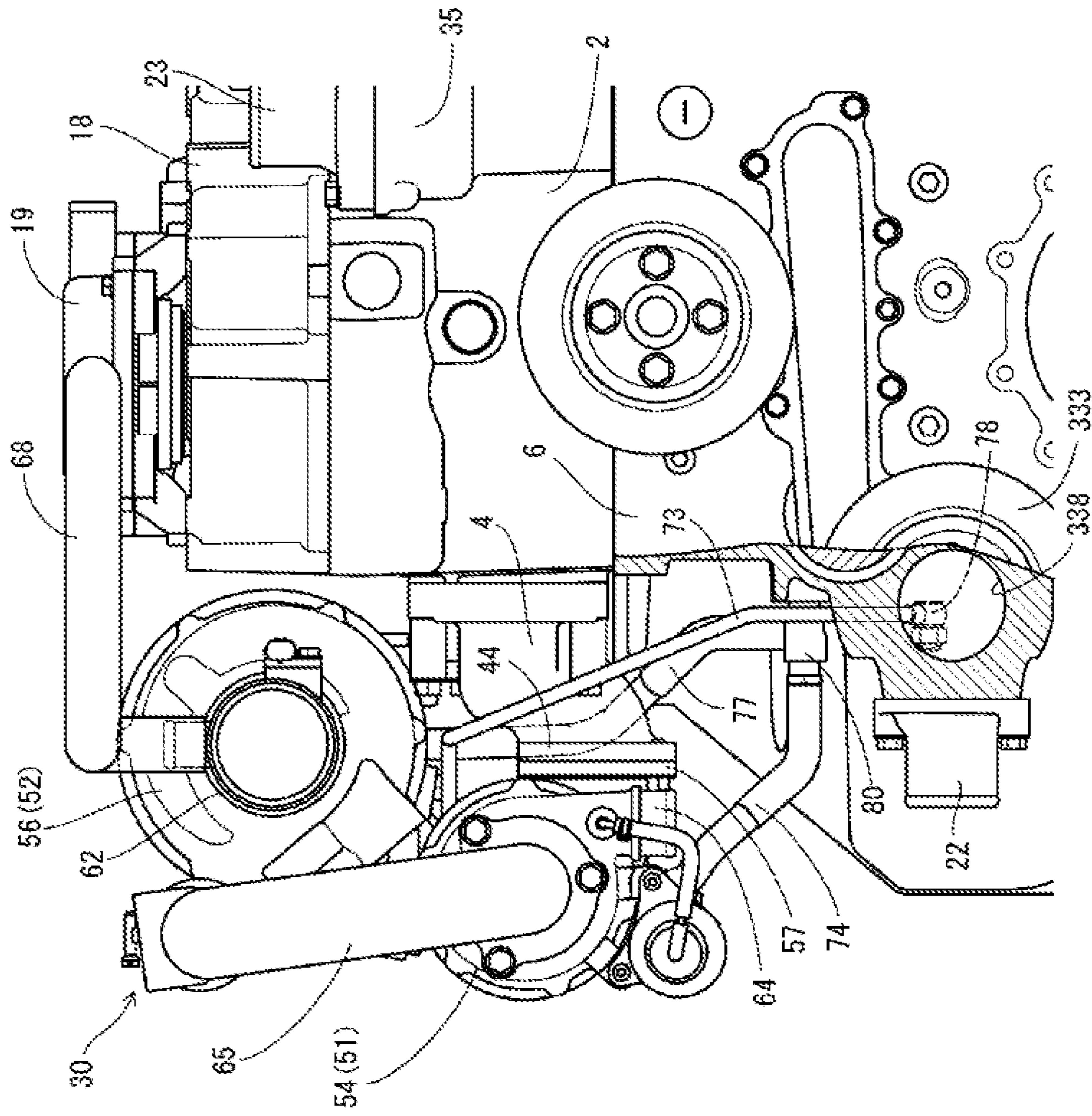


FIG. 24

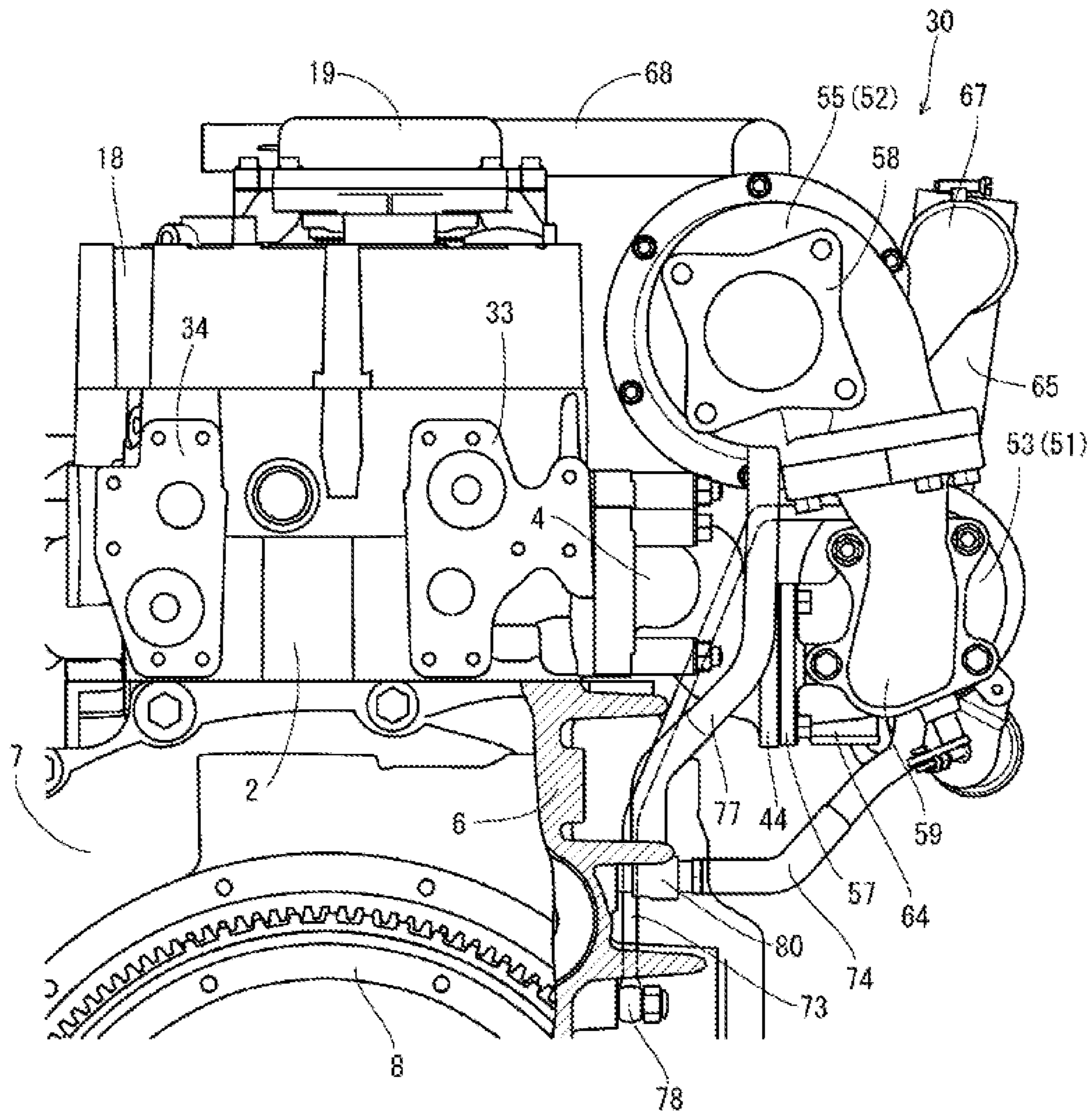
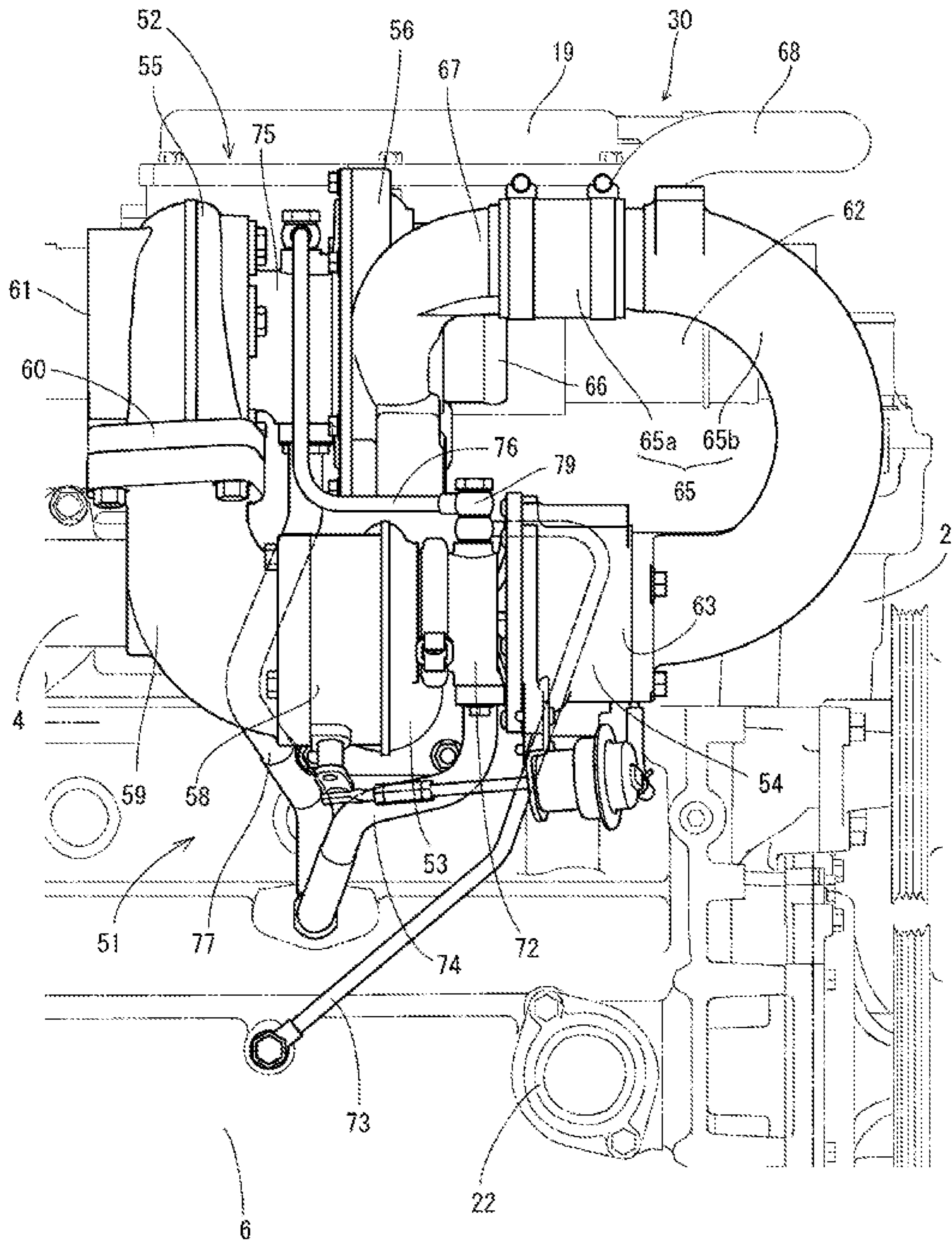


FIG. 25



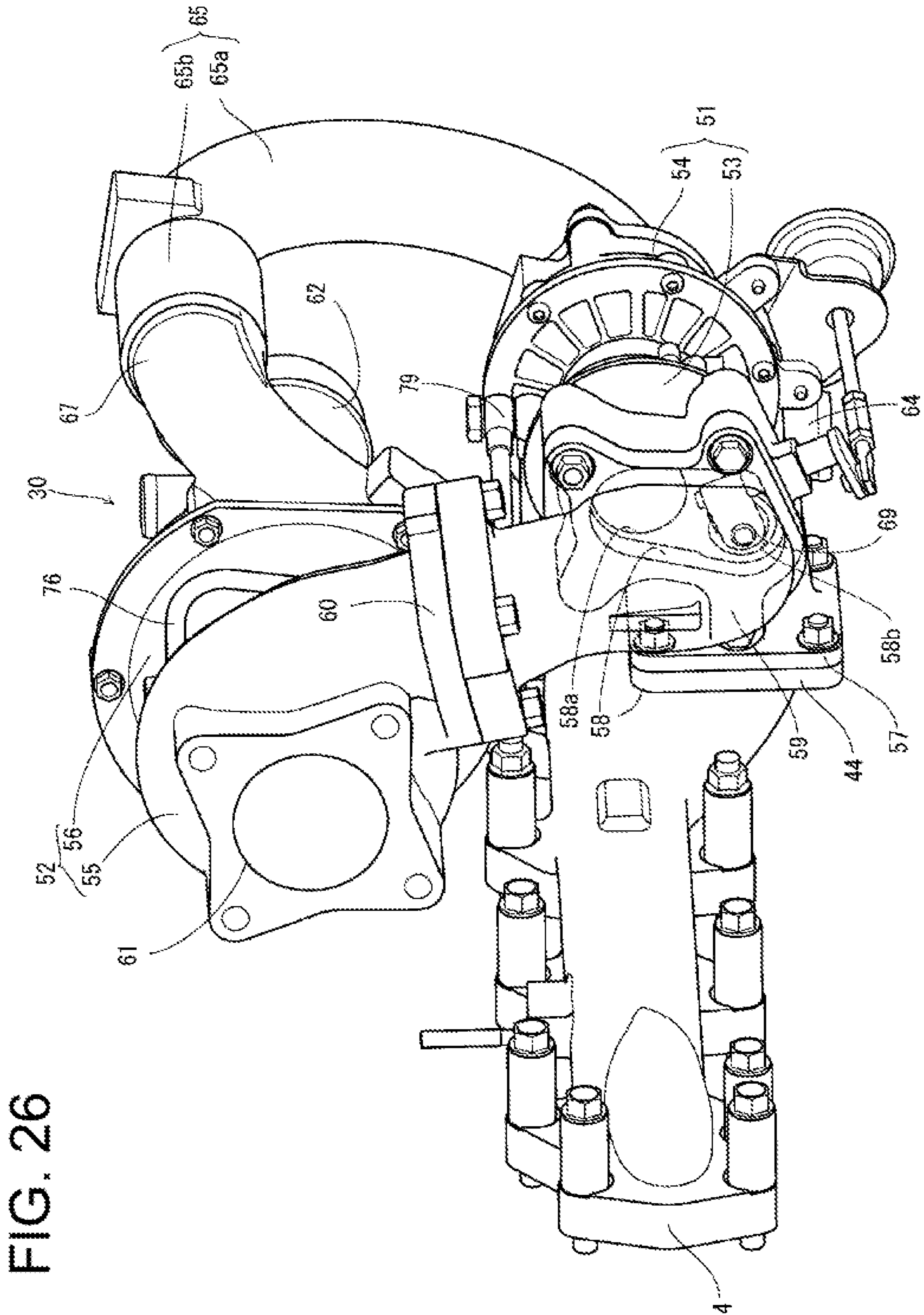


FIG. 26

FIG. 27

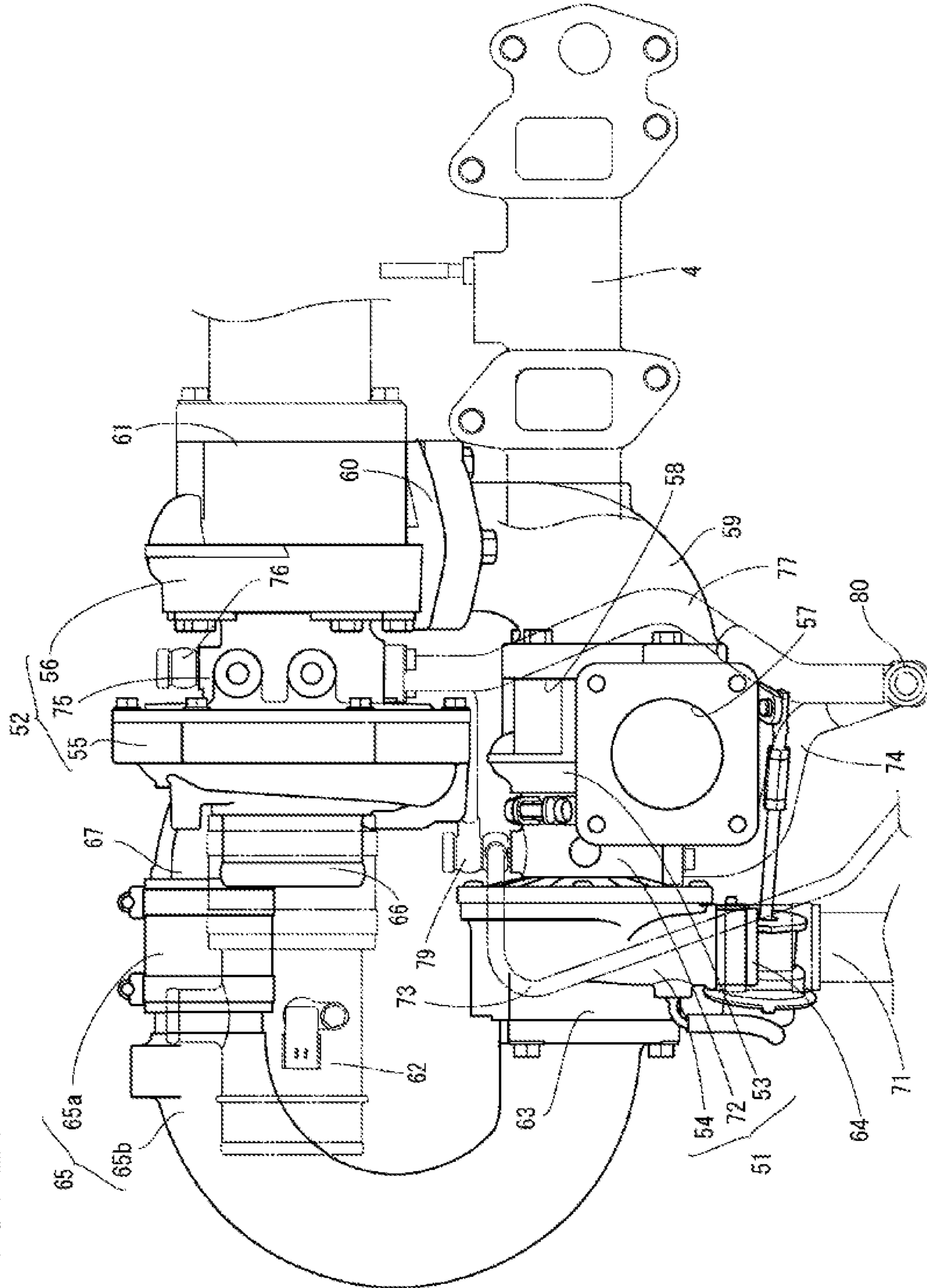


FIG. 28

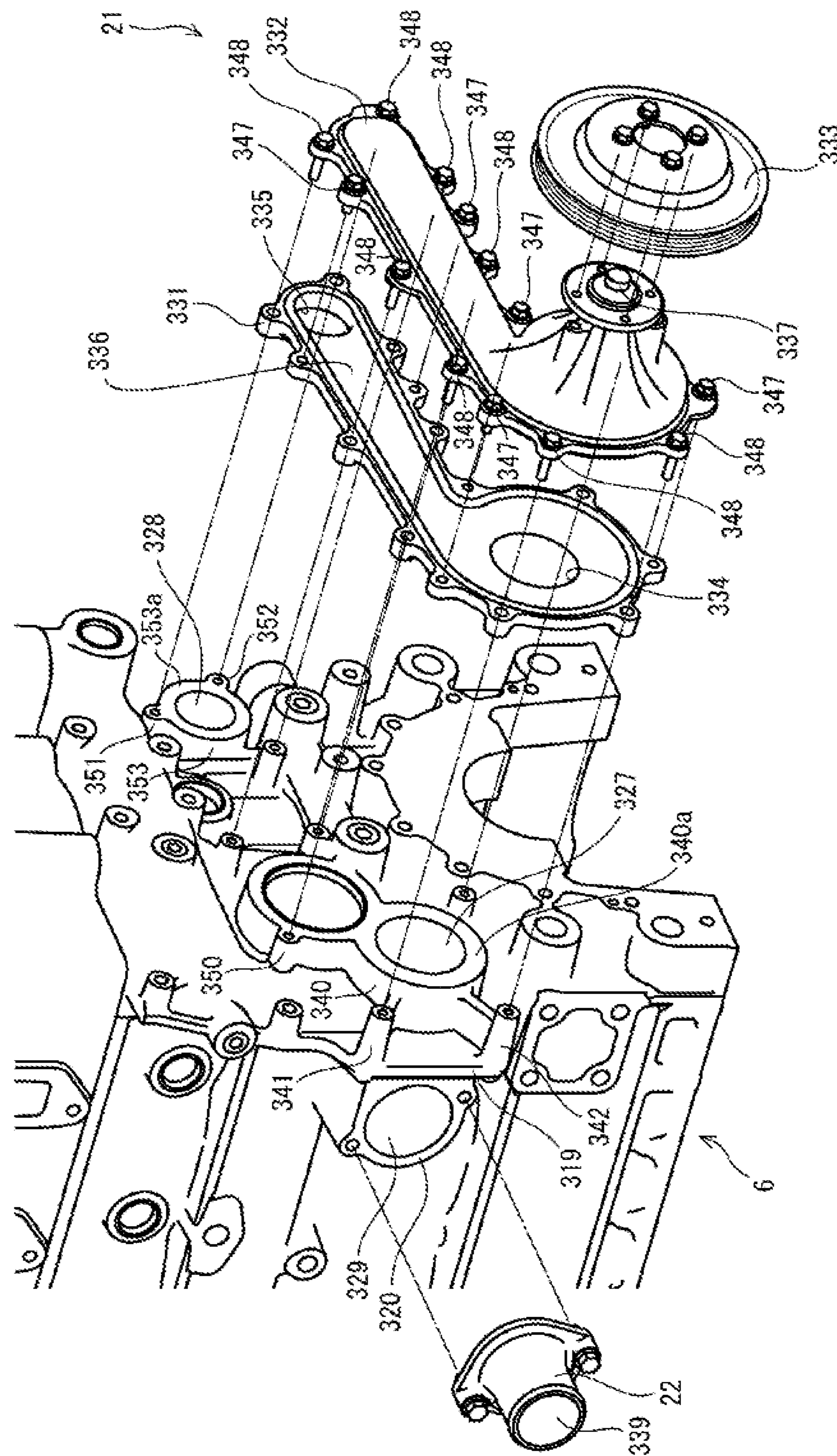
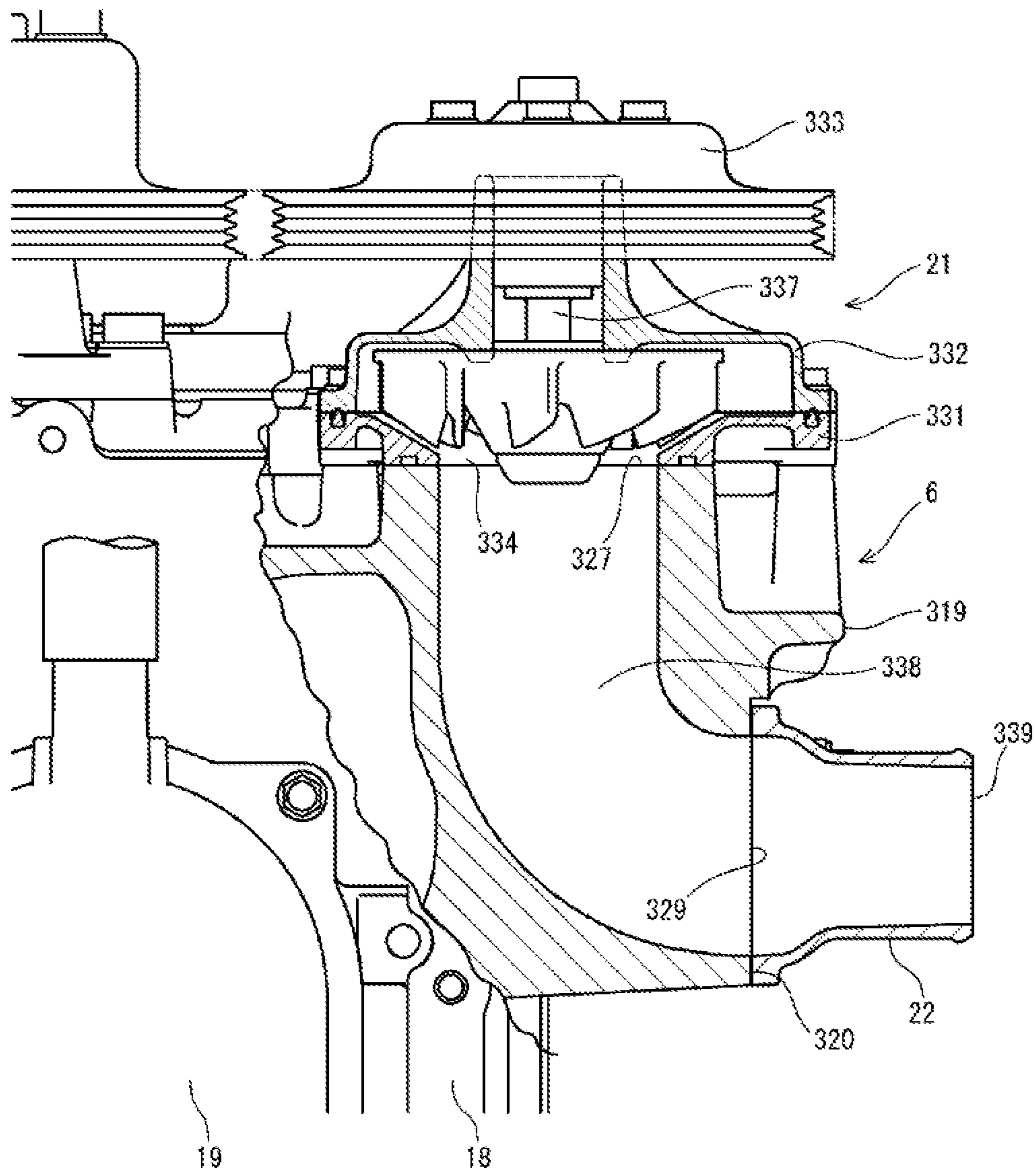


FIG. 29



1**ENGINE DEVICE**

CROSS-REFERENCE

This is a continuation of U.S. application Ser. No. 16/091, 855 filed Oct. 5, 2018, which is a US National Stage Application under 35 U.S.C. § 371 of International Application No. PCT/JP2017/012963 filed Mar. 29, 2017, which claims foreign priority of JP2016-078467 filed Apr. 8, 2016, the disclosures of which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD

The present invention relates to an engine device including a turbocharger.

BACKGROUND ART

Conventionally, an engine device is equipped with a turbocharger that uses exhaust energy to compress fresh air, in order to increase an air density in an engine cylinder, for the purpose of enhancing an engine output and improving a fuel efficiency (see Patent Literature 1 (PTL 1)). In a diesel engine, a large amount of high-density air is supplied into a cylinder to combust a large amount of fuel, which can increase an engine output and an engine torque can be increased, and also can facilitate mixing of the fuel and air to thereby reduce the amount of NOx discharge with suppression of premix combustion.

Since a single-stage turbocharger including a single turbocharger has a limitation against requirement of a high-output engine, an engine equipped with a two-stage turbocharger in which two turbochargers of a high-pressure stage and a low-pressure stage are coupled in series has been proposed (see Patent Literature 2 (PTL 2)).

CITATION LIST

Patent Literature

PTL 1: Japanese Patent No. 4517550

PTL 2: Japanese Patent No. 5237785

SUMMARY OF INVENTION

Technical Problem

An installation space for a diesel engine varies depending on a work vehicle (such as a construction machine or an agricultural machine) to which the diesel engine is installed. Recently, due to demand for weight reduction and compactification, the installation space is often restricted (confined). It therefore is necessary that component parts of the diesel engine are arranged in a compact layout. In addition to such a problem of the restricted installation space, a structure with a high rigidity is required of a cylinder head because component parts such as an EGR device and a turbocharger are coupled to and supported by the cylinder head.

Arranging a high-pressure stage turbocharger and a low-pressure stage turbocharger of a two-stage turbocharger one above the other at a position distant from an exhaust manifold as in an engine device of PTL 2 results in a high moment exerted on an outlet of the exhaust manifold which supports the two-stage turbocharger. Consequently, the two-stage turbocharger is supported with a lowered rigidity. In addition, a bypass path provided on a turbine side of the

2

high-pressure stage is external piping, and therefore a piping structure of the two-stage turbocharger is complicated, which makes assemblage to the engine device troublesome.

A technical problem of the present invention is to provide an engine device that is improved based on studies on the existing circumstances as mentioned above.

Solution to Problem

An aspect of the present invention is an engine device including: an exhaust manifold and an intake manifold, the exhaust manifold being disposed on one of left and right sides of a cylinder head, the intake manifold being disposed on the other of the left and right sides of the cylinder head; and a turbocharger that uses fluid energy of an exhaust gas discharged from the exhaust manifold, to compress fresh air to be flowed into the intake manifold, the turbocharger being constituted by a two-stage turbocharger including a high-pressure turbocharger coupled to the exhaust manifold and a low-pressure turbocharger coupled to the high-pressure turbocharger, the high-pressure turbocharger being disposed on one of left and right lateral sides of the exhaust manifold, the low-pressure turbocharger being disposed above the exhaust manifold.

The engine device may be configured such that: the high-pressure turbocharger includes a high-pressure turbine and a high-pressure compressor, the high-pressure turbine being in communication with an exhaust gas outlet of the exhaust manifold, the high-pressure compressor being configured to supply compressed air to the intake manifold; the low-pressure turbocharger includes a low-pressure turbine and a low-pressure compressor, the low-pressure turbine having an exhaust gas inlet that is in communication with an exhaust gas outlet of the high-pressure turbine through an exhaust relay pipe, the low-pressure compressor having a fresh air outlet that is in communication with a fresh air inlet of the high-pressure compressor through a fresh air relay pipe; and the low-pressure compressor is disposed above the high-pressure turbine, the high-pressure compressor is disposed on one of front and rear sides relative to the high-pressure turbine, and the low-pressure turbine is disposed on the other of the front and rear sides relative to the low-pressure compressor.

The engine device may be configured such that: the exhaust manifold has an exhaust gas outlet that discharges an exhaust gas, the exhaust gas outlet being opened toward one of left and right lateral sides; the high-pressure turbine has an exhaust gas inlet that is opened toward the exhaust manifold, and has an exhaust gas outlet that is opened toward the other of front and rear sides; the low-pressure turbine has an exhaust gas inlet that is opened downward, and has an exhaust gas outlet that is opened toward the other of front and rear sides; the exhaust gas outlet of the exhaust manifold and the exhaust gas inlet of the high-pressure turbine that are opposed to each other are coupled, to fix the high-pressure turbocharger on one of left and right lateral sides of the exhaust manifold; and the exhaust gas outlet of the high-pressure turbine is fixed to one end of the exhaust relay pipe having an L-shape, the exhaust gas inlet of the low-pressure turbine is fixed to the other end of the exhaust relay pipe, and the low-pressure turbocharger is fixed above the high-pressure turbocharger.

The engine device may be configured such that: the high-pressure compressor has a fresh air inlet that is opened toward one of front and rear sides, and has a fresh air outlet that is opened downward; the low-pressure compressor has a fresh air inlet that is opened toward one of front and rear

sides, and has a fresh air outlet that protrudes from one of left and right lateral sides and then is directed toward one of front and rear sides; and one end of the fresh air relay pipe having a U-shape is fixed to the fresh air inlet of the high-pressure compressor, and the other end of the fresh air relay pipe is coupled to the fresh air outlet of the low-pressure compressor.

The engine device may be configured such that: a blow-by gas recirculation device that takes a blow-by gas in is provided on the cylinder head, and a blow-by gas outlet disposed on one of front and rear sides of the blow-by gas recirculation device is coupled to an air supply pipe through a recirculation hose, the air supply pipe being coupled to the fresh air inlet of the low-pressure compressor; and the air supply pipe is disposed between the fresh air relay pipe and the cylinder head.

The engine device may be configured such that: the exhaust gas outlet of the high-pressure turbine is provided with a turbine discharge hole, a bypass hole, and a wastegate valve, the turbine discharge hole being configured to discharge an exhaust gas for rotating a turbine wheel, the bypass hole allowing the exhaust gas inlet and the exhaust gas outlet to communicate with each other, the wastegate valve being configured to open and close the bypass hole.

Advantageous Effects of Invention

In an aspect of the present invention, the high-pressure turbocharger with a low capacity is disposed opposed to the exhaust manifold, while the low-pressure turbocharger with a high capacity is disposed above the exhaust manifold. This enables the exhaust manifold and the two-stage turbocharger to be compactly arranged in a space existing on a left lateral side of the engine, and also enables a topmost portion of the two-stage turbocharger to be positioned lower than a topmost portion of the engine device. This can contribute to downsizing of the engine device. In addition, the low-pressure turbocharger can be disposed close to the cylinder head to which the exhaust manifold is coupled, and thus the two-stage turbocharger can be fixed with a high rigidity.

In an aspect of the present invention, the high-pressure turbine is coupled to the exhaust manifold, and the high-pressure turbocharger is supported with a high rigidity. In this condition, the low-pressure turbine is coupled to an upper surface of the exhaust relay pipe which is coupled to the high-pressure turbocharger. Thereby, the low-pressure turbocharger can be supported from below by the high-pressure turbocharger. Since the low-pressure turbocharger is installed close to a position above the exhaust manifold, the center of gravity of the low-pressure turbocharger is in the vicinity of a position above the position where the exhaust manifold is coupled to the high-pressure turbocharger. Accordingly, the two-stage turbocharger can be compactly supported with a high rigidity in the vicinity of the engine device.

In an aspect of the present invention, the high-pressure compressor and the low-pressure compressor are coupled by the U-shaped fresh air relay pipe, and a front portion of the low-pressure turbocharger can be fixed to the high-pressure turbocharger which is supported with a high rigidity by the exhaust manifold. The fresh air inlet and the fresh air outlet of the low-pressure compressor are extended in the same direction, and can be easily coupled to the air supply pipe which is in communication with an air cleaner (not shown) and to the fresh air relay pipe, respectively. This configuration can enhance a workability in assembling.

In an aspect of the present invention, the air supply pipe is coupled to the low-pressure turbocharger which is an upper component of the two-stage turbocharger, and is disposed close to the cylinder head. Thus, the distance between the air supply pipe and the blow-by gas recirculation device disposed above the cylinder head can be shortened. This makes it possible to shorten the recirculation hose. Since the air supply pipe is disposed in a space surrounded by the fresh air relay pipe and the cylinder head, the air supply pipe can be prevented from being damaged by an external force which may be applied in a coupling portion coupled to a resin pipe which is connected to the air cleaner (not shown).

In an aspect of the present invention, the exhaust gas outlet of the high-pressure turbine is provided with the turbine discharge hole and the bypass hole that are arranged side-by-side. With this configuration, it is possible to set whether to perform a compression operation by the high-pressure turbocharger in accordance with a rotational frequency of the engine device. Accordingly, with efficient use of exhaust energy, the two-stage turbocharger can stabilize the amount of fresh air to be supplied to the combustion chamber, and can reduce the amount of back smoke discharge while increasing an engine output.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 A front view of an engine.

FIG. 2 A rear view of the engine.

FIG. 3 A left side view of the engine.

FIG. 4 A right side view of the engine.

FIG. 5 A top plan view of the engine.

FIG. 6 A bottom plan view of the engine.

FIG. 7 A perspective view of the engine as viewed from diagonally front.

FIG. 8 A perspective view of the engine as viewed from diagonally rear.

FIG. 9 An enlarged perspective view of a cylinder head as viewed from an intake manifold side.

FIG. 10 An exploded perspective view of the cylinder head as viewed from an exhaust manifold side.

FIG. 11 An exploded perspective view of the cylinder head as viewed from the intake manifold side.

FIG. 12 A top plan view of the cylinder head.

FIG. 13 A front view of the cylinder head.

FIG. 14 A perspective cross-sectional view of the cylinder head and an EGR device.

FIG. 15 A perspective cross-sectional view of the cylinder head and the exhaust manifold.

FIG. 16 A perspective cross-sectional view of a coupling portion of the cylinder head coupled to an EGR cooler.

FIG. 17 A perspective cross-sectional view of the EGR device.

FIG. 18 A top plan view of the EGR device.

FIG. 19 An exploded perspective view of the EGR device.

FIG. 20 An exploded view of the coupling portion of the cylinder head coupled to the EGR cooler.

FIG. 21 A cross-sectional view of the coupling portion of the cylinder head coupled to the EGR cooler.

FIG. 22 A left side view of the engine for illustrating arrangement of a two-stage turbocharger.

FIG. 23 An enlarged rear view of the engine.

FIG. 24 An enlarged front view of the engine.

FIG. 25 A left side view of the two-stage turbocharger.

FIG. 26 A perspective view of the two-stage turbocharger.

FIG. 27 A right side view of the two-stage turbocharger.

FIG. 28 An exploded perspective view of a coolant pump.

FIG. 29 A partial cross-sectional view of a coolant pump attaching portion.

DESCRIPTION OF EMBODIMENT

In the following, an embodiment of the present invention will be described with reference to the drawings. First, referring to FIG. 1 to FIG. 8, an overall structure of a diesel engine (engine device) 1 will be described. In the descriptions below, opposite side portions parallel to a crankshaft 5 (side portions on opposite sides relative to the crankshaft 5) will be defined as left and right, a side where a flywheel housing 7 is disposed will be defined as front, and a side where a cooling fan 9 is disposed will be defined as rear. For convenience, these are used as a benchmark for a positional relationship of left, right, front, rear, up, and down in the diesel engine 1.

As shown in FIG. 1 to FIG. 8, an intake manifold 3 and an exhaust manifold 4 are disposed in one side portion and the other side portion of the diesel engine 1 parallel to the crankshaft 5. In the embodiment, the intake manifold 3 provided on a right surface of a cylinder head 2 is formed integrally with the cylinder head 2. The exhaust manifold 4 is provided on a left surface of the cylinder head 2. The cylinder head 2 is mounted on a cylinder block 6 in which the crankshaft 5 and a piston (not shown) are disposed.

The crankshaft 5 has its front and rear distal ends protruding from front and rear surfaces of the cylinder block 6. The flywheel housing 7 is fixed to one side portion of the diesel engine 1 (in the embodiment, a front surface side of the cylinder block 6) intersecting the crankshaft 5. A flywheel 8 is disposed in the flywheel housing 7. The flywheel 8, which is pivotally supported on the front end side of the crankshaft 5, is configured to rotate integrally with the crankshaft 5. The flywheel 8 is configured such that power of the diesel engine 1 is extracted to an actuating part of a work machine (for example, a hydraulic shovel, a forklift, or the like) through the flywheel 8. The cooling fan 9 is disposed in the other side portion of the diesel engine 1 (in the embodiment, a rear surface side of the cylinder block 6) intersecting the crankshaft 5. A rotational force is transmitted from the rear end side of the crankshaft 5 to the cooling fan 9 through a V-belt 10.

An oil pan 11 is disposed on a lower surface of the cylinder block 6. A lubricant is stored in the oil pan 11. The lubricant in the oil pan 11 is suctioned by an oil pump (not shown) disposed on the right surface side of the cylinder block 6, the oil pump being arranged in a coupling portion where the cylinder block 6 is coupled to the flywheel housing 7. The lubricant is then supplied to lubrication parts of the diesel engine 1 through an oil cooler 13 and an oil filter 14 that are disposed on the right surface of the cylinder block 6. The lubricant supplied to the lubrication parts is then returned to the oil pan 11. The oil pump (not shown) is configured to be driven by rotation of the crankshaft 5.

In the coupling portion where the cylinder block 6 is coupled to the flywheel housing 7, a fuel feed pump 15 for feeding a fuel is attached. The fuel feed pump 15 is disposed below an EGR device 24. A common rail 16 is fixed to a side surface of the cylinder block 6 at a location below the intake manifold 3 of the cylinder head 2. The common rail 16 is disposed above the fuel feed pump 15. Injectors (not shown) for four cylinders are provided on an upper surface of the cylinder head 2 which is covered with a head cover 18. Each of the injectors has a fuel injection valve of electromagnetic-

Each of the injectors is connected to a fuel tank (not shown) through the fuel feed pump 15 and the common rail 16 having a cylindrical shape. The fuel tank is mounted in a work vehicle. A fuel in the fuel tank is pressure-fed from the fuel feed pump 15 to the common rail 16, so that a high-pressure fuel is stored in the common rail 16. By controlling the opening/closing of the fuel injection valves of the injectors, the high-pressure fuel in the common rail 16 is injected from the injectors to the respective cylinders of the diesel engine 1.

A blow-by gas recirculation device 19 is provided on an upper surface of the head cover 18 covering intake and exhaust valves (not shown), etc. disposed on the upper surface of the cylinder head 2. The blow-by gas recirculation device 19 takes in a blow-by gas that has leaked out of a combustion chamber of the diesel engine 1 or the like toward the upper surface of the cylinder head 2. A blow-by gas outlet of the blow-by gas recirculation device 19 is in communication with an intake part of a two-stage turbocharger 30 through a recirculation hose 68. A blow-by gas, from which a lubricant component is removed in the blow-by gas recirculation device 19, is then recirculated to the intake manifold 3 via the two-stage turbocharger 30.

An engine starting starter 20 is attached to the flywheel housing 7. The engine starting starter 20 is disposed below the exhaust manifold 4. A position where the engine starting starter 20 is attached to the flywheel housing 7 is below a coupling portion where the cylinder block 6 is coupled to the flywheel housing 7.

A coolant pump 21 for smoothing a coolant is provided in a portion of the rear surface of the cylinder block 6, the portion being a little left-hand. The coolant pump 21 is disposed below the cooling fan 9. Rotation of the crankshaft 5 causes the coolant pump 21 as well as the cooling fan 9 to be driven through the cooling fan driving V-belt 10. Driving the coolant pump 21 causes a coolant in a radiator (not shown) mounted in the work vehicle to be supplied to the coolant pump 21. The coolant is then supplied to the cylinder head 2 and the cylinder block 6, to cool the diesel engine 1.

A coolant inlet pipe 22 disposed below the exhaust manifold 4 is provided on the left surface of the cylinder block 6 and is fixed at a height equal to the height of the coolant pump 21. The coolant inlet pipe 22 is in communication with a coolant outlet of the radiator. A coolant outlet pipe 23 that is in communication with a coolant inlet of the radiator is fixed at a position above a rear surface of the cylinder head 2. The cylinder head 2 has a coolant drainage 35 that protrudes rearward from the intake manifold 3. The coolant outlet pipe 23 is provided on an upper surface of the coolant drainage 35.

The inlet side of the intake manifold 3 is coupled to an air cleaner (not shown) via a collector (EGR main body case) 25 of an EGR device 24 (exhaust-gas recirculation device) which will be described later. Fresh air (outside air) suctioned by the air cleaner is subjected to dust removal and purification in the air cleaner, then fed to the intake manifold 3 through the collector 25, and then supplied to the respective cylinders of the diesel engine 1. In the embodiment, the collector 25 of the EGR device 24 is coupled to the right side of the intake manifold 3 which is formed integrally with the cylinder head 2 to form the right surface of the cylinder head 2. That is, an outlet opening of the collector 25 of the EGR device 24 is coupled to an inlet opening of the intake manifold 3 provided on the right surface of the cylinder head 2. In this embodiment, the collector 25 of the EGR device 24 is coupled to the air cleaner via an intercooler (not shown) and the two-stage turbocharger 30, as will be described later.

The EGR device **24** includes: the collector **25** serving as a relay pipe passage that mixes a recirculation exhaust gas of the diesel engine **1** (an EGR gas from the exhaust manifold **4**) with fresh air (outside air from the air cleaner), and supplies a mixed gas to the intake manifold **3**; an intake throttle member **26** that communicates the collector **25** with the air cleaner; a recirculation exhaust gas tube **28** that constitutes a part of a recirculation flow pipe passage connected to the exhaust manifold **4** via an EGR cooler **27**; and an EGR valve member **29** that communicates the collector **25** with the recirculation exhaust gas tube **28**.

The EGR device **24** is disposed on the right lateral side of the intake manifold **3** in the cylinder head **2**. The EGR device **24** is fixed to the right surface of the cylinder head **2**, and is in communication with the intake manifold **3** in the cylinder head **2**. In the EGR device **24**, the collector **25** is coupled to the intake manifold **3** on the right surface of the cylinder head **2**, and an EGR gas inlet of the recirculation exhaust gas tube **28** is coupled and fixed to a front portion of the intake manifold **3** on the right surface of the cylinder head **2**. The EGR valve member **29** and the intake throttle member **26** are coupled to the front and rear of the collector **25**, respectively. An EGR gas outlet of the recirculation exhaust gas tube **28** is coupled to the rear end of the EGR valve member **29**.

The EGR cooler **27** is fixed to the front surface of the cylinder head **2**. The coolant and the EGR gas flowing in the cylinder head **2** flows into and out of the EGR cooler **27**. In the EGR cooler **27**, the EGR gas is cooled. EGR cooler coupling bases **33**, **34** for coupling the EGR cooler **27** to the front surface of the cylinder head **2** protrude from left and right portions of the front surface of the cylinder head **2**. The EGR cooler **27** is coupled to the coupling bases **33**, **34**. That is, the EGR cooler **27** is disposed on the front side of the cylinder head **2** and at a position above the flywheel housing **7** such that a rear end surface of the EGR cooler **27** and the front surface of the cylinder head **2** are spaced from each other.

The two-stage turbocharger **30** is disposed on a lateral side (in the embodiment, the left lateral side) of the exhaust manifold **4**. The two-stage turbocharger **30** includes a high-pressure turbocharger **51** and a low-pressure turbocharger **52**. The high-pressure turbocharger **51** includes a high-pressure turbine **53** in which a turbine wheel (not shown) is provided and a high-pressure compressor **54** in which a blower wheel (not shown) is provided. The low-pressure turbocharger **52** includes a low-pressure turbine **55** in which a turbine wheel (not shown) is provided and a low-pressure compressor **56** in which a blower wheel (not shown) is provided.

An exhaust gas inlet **57** of the high-pressure turbine **53** is coupled to the exhaust manifold **4**. An exhaust gas inlet **60** of the low-pressure turbine **55** is coupled to an exhaust gas outlet **58** of the high-pressure turbine **53** via a high-pressure exhaust gas tube **59**. An exhaust gas introduction side end portion of an exhaust gas discharge pipe (not shown) is coupled to an exhaust gas outlet **61** of the low-pressure turbine **55**. A fresh air supply side (fresh air outlet side) of the air cleaner (not shown) is connected to a fresh air inlet port (fresh air inlet) **63** of the low-pressure compressor **56** via an air supply pipe **62**. A fresh air inlet port **66** of the high-pressure compressor **54** is coupled to a fresh air supply port (fresh air outlet) **64** of the low-pressure compressor **56** via a low-pressure fresh air passage pipe **65**. A fresh air introduction side of the intercooler (not shown) is connected to a fresh air supply port **67** of the high-pressure compressor **54** via a high-pressure fresh air passage pipe **71**.

The high-pressure turbocharger **51** is coupled to the exhaust gas outlet **58** of the exhaust manifold **4**, and is fixed to the left lateral side of the exhaust manifold **4**. On the other hand, the low-pressure turbocharger **52** is coupled to the high-pressure turbocharger **51** via the high-pressure exhaust gas tube **59** and the low-pressure fresh air passage pipe **65**, and is fixed above the exhaust manifold **4**. Thus, the exhaust manifold **4** and the high-pressure turbocharger **51** with a small diameter are disposed side-by-side with respect to the left-right direction below the low-pressure turbocharger **52** with a large diameter. As a result, the two-stage turbocharger **30** is arranged so as to surround the left surface and the upper surface of the exhaust manifold **4**. That is, the exhaust manifold **4** and the two-stage turbocharger **30** are arranged so as to form a rectangular shape in a rear view (or front view), and are compactly fixed to the left surface of the cylinder head **2**.

Next, referring to FIG. **9** to FIG. **16**, a configuration of the cylinder head **2** will be described. As shown in FIG. **9** to FIG. **16**, the cylinder head **2** is provided with a plurality of intake fluid passages **36** for taking fresh air into a plurality of intake ports (not shown) and a plurality of exhaust fluid passages **37** for emitting an exhaust gas from a plurality of exhaust ports. The intake manifold **3** which aggregates the plurality of intake fluid passages **36** is formed integrally with a right side portion of the cylinder head **2**. Since the cylinder head **2** is integrated with the intake manifold **3**, a gas sealability between the intake manifold **3** and the intake fluid passages **36** can be enhanced, and in addition, the rigidity of the cylinder head **2** can be increased.

The cylinder head **2** is configured such that the exhaust manifold **4** is coupled to the left surface of the cylinder head **2** which is opposite to the right surface where the intake manifold **3** is provided, and the EGR cooler **27** is coupled to the front surface (a surface on the flywheel housing **7** side) of the cylinder head **2** which is adjacent to the left and right surfaces. Coupling bases (EGR cooler coupling bases) **33**, **34** to which the EGR cooler **27** is coupled are provided so as to protrude from the front surface of the cylinder head **2**. The coupling bases **33**, **34** are provided therein with EGR gas fluid passages (EGR gas relay fluid passages) **31**, **32** and coolant passages (coolant relay fluid passages) **38**, **39**.

Since the EGR gas relay fluid passages **31**, **32** and the coolant passages **38**, **39** are provided in the coupling bases **33**, **34** to which the EGR cooler **27** is coupled, it is not necessary that coolant piping and EGR gas piping are disposed between the EGR cooler **27** and the cylinder head **2**. This can give a sealability to a coupling portion coupled to the EGR cooler **27** without any influence of, for example, extension and contraction of piping caused by the EGR gas or the coolant. This can also enhance a resistance (structural stability) against external fluctuation factors such as heat and vibration, and moreover can make the configuration compact.

The cylinder head **2** includes an upstream EGR gas relay fluid passage **31** through which a front portion of the left surface is in communication with the front surface. An EGR gas outlet **41** disposed at the front end of the exhaust manifold **4** is in communication with the upstream EGR gas relay fluid passage **31**. The cylinder head **2** also includes a downstream EGR gas relay fluid passage **32** through which a front portion of the right surface (on the front side of the intake manifold **3**) is in communication with the front surface. The EGR gas inlet of the recirculation exhaust gas tube **28** is in communication with the downstream EGR gas relay fluid passage **32**. The cylinder head **2** has the EGR cooler coupling bases **33**, **34** which are formed by left and

right edges of the front surface of the cylinder head 2 (a front-left corner portion and a front-right corner portion of the cylinder head 2) being protruded frontward. The upstream EGR gas relay fluid passage 31 is provided inside the coupling base 33, and the downstream EGR gas relay fluid passage 32 is provided inside the coupling base 34.

The EGR device 24 is coupled to the intake manifold 3 which is provided on the right surface of the cylinder head 2 so as to protrude therefrom. The intake manifold 3 is disposed in a portion of the right surface of the cylinder head 2, the portion being relatively close to the rear side (the cooling fan 9 side). The intake manifold 3 is formed by a lower portion of the right surface of the cylinder head 2 being protruded rightward. The intake manifold 3 has an intake inlet 40 at its middle portion with respect to the front-rear direction. An intake outlet 83 of the collector 25 of the EGR device 24 is coupled to the intake inlet 40 of the intake manifold 3 which protrudes from the right surface of the cylinder head 2, and the EGR device 24 is fixed to the right lateral side of the cylinder head 2.

On the front side (the flywheel housing 7 side) of the right surface of the cylinder head 2, the coupling base 34 coupled to the EGR cooler 27 protrudes frontward, and an EGR gas outlet of the downstream EGR gas relay fluid passage 32 is opened in a right surface of the coupling base 34. One end of the recirculation exhaust gas tube 28 of the EGR device 24 is coupled to the right surface of the coupling base 34, and thereby the collector 25 of the EGR device 24 is in communication with the downstream EGR gas relay fluid passage 32 provided inside the cylinder head 2 via the recirculation exhaust gas tube 28 and the EGR valve member 29.

On the rear side (the cooling fan 9 side) of the right surface of the cylinder head 2, the coolant drainage (thermostat case) 35 whose upper surface is opened to communicate with a coolant outlet pipe (thermostat cover) 23 protrudes rearward, and a thermostat (not shown) is installed therein. The coolant drainage 35 is offset at the rear of the right surface of the cylinder head 2, and therefore it is possible that the V-belt 10 wound on a fan pulley 9a to which the cooling fan 9 is fixed extends through a space below the coolant drainage 35. Thus, the length of the diesel engine 1 in the front-rear direction can be shortened. The coolant drainage 35 also protrudes from the right surface of the cylinder head 2. On the right surface of the cylinder head 2, the intake manifold 3 and the coolant drainage 35 are arranged one behind the other with respect to the front-rear direction.

On the front side (the flywheel housing 7 side) of the left surface of the cylinder head 2, the coupling base 33 coupled to the EGR cooler 27 protrudes frontward, and an EGR gas inlet 96 of the upstream EGR gas relay fluid passage 31 is opened in a left surface of the coupling base 33. That is, in the left surface of the cylinder head 2, the EGR gas inlet 96 of the upstream EGR gas relay fluid passage 31 and exhaust gas outlets of the plurality of exhaust fluid passages 37 are arranged in the front-rear direction, and are opened. The exhaust manifold 4 has, in its right surface which is coupled to the left surface of the cylinder head 2, the EGR gas outlet 41 which is in communication with the upstream EGR gas relay fluid passage 31 and exhaust gas inlets 42 which are in communication with the plurality of exhaust fluid passages 37 are arranged in the front-rear direction, and are opened. Since the EGR inlet and the exhaust gas outlets are arranged side-by-side in the same surface of the cylinder head 2, it is easy for a coupling portion where the cylinder head 2 is

coupled to the exhaust manifold 4 to obtain an airtightness (gas sealability) by sandwiching a single gasket 45 therebetween.

The exhaust manifold 4 is provided therein with an exhaust aggregate part 43 which is in communication with the EGR gas outlet 41 and the exhaust gas inlets 42. The exhaust aggregate part 43 is disposed such that its longitudinal direction is parallel to the front-rear direction. An exhaust gas outlet 44 which is in communication with the exhaust aggregate part 43 is opened in a rear portion of the left surface of the exhaust manifold 4. The exhaust manifold 4 is configured such that, after an exhaust gas coming from the exhaust fluid passages 37 of the cylinder head 2 flows into the exhaust aggregate part 43 via the exhaust gas inlets 42, part of the exhaust gas serves as an EGR gas and flows into the upstream EGR gas relay fluid passage 31 of the cylinder head 2 via the EGR gas outlet 41 while the rest of the exhaust gas flows into the two-stage turbocharger 30 via the exhaust gas outlet 44.

On the front surface of the cylinder head 2, the left and right pair of EGR cooler coupling bases 33, 34 are disposed on the exhaust manifold 4 side and on the intake manifold 3 side, respectively. The EGR cooler coupling base 33 has the upstream EGR gas relay fluid passage 31 through which the EGR gas fluid passage of the exhaust manifold 4 communicates with the EGR gas fluid passage of the EGR cooler 27. The EGR cooler coupling base 34 has the downstream EGR gas relay fluid passage 32 through which the EGR gas fluid passage of the EGR device 24 communicates with the EGR gas fluid passage of the EGR cooler 27. The EGR cooler coupling base 33 also has the downstream coolant passage 38 to which a coolant is discharged from the EGR cooler 27. The EGR cooler coupling base 34 has the upstream coolant passage 39 that supplies a coolant to the EGR device 24 and to the EGR cooler 27.

Since the EGR cooler coupling bases 33, 34 are configured in a protruding manner, there is no need for EGR gas piping that communicates the exhaust manifold 4, the EGR cooler 27, and the EGR device 24. Thus, the number of coupling portions of the EGR gas fluid passage is small. Accordingly, in the diesel engine 1 that aims to reduce NOx by the EGR gas, EGR gas leakage can be reduced, and moreover deformation can be suppressed which may otherwise be caused by a change in a stress due to extension and contraction of piping. Since the EGR gas relay fluid passages 31, 32 and the coolant passages 38, 39 are provided in the EGR cooler coupling bases 33, 34, the shapes of the fluid passages 31, 32, 38, 39 formed in the cylinder head 2 are simplified, so that the cylinder head 2 can be easily formed by casting without using a complicated core.

The EGR cooler coupling base 33 on the intake manifold 3 side and the EGR cooler coupling base 34 on the exhaust manifold 4 side are distant from each other. This can suppress a mutual influence between thermal deformations of the coupling bases 33, 34. Accordingly, gas leakage and damage of coupling portions where the EGR cooler coupling bases 33, 34 are coupled to the EGR cooler 27 can be prevented, and in addition, a balance of the rigidity of the cylinder head 2 can be maintained. Moreover, the volume of the front surface of the cylinder head 2 can be reduced, which leads to weight reduction of the cylinder head 2. Furthermore, it is possible that the EGR cooler 27 is disposed at a distance from the front surface of the cylinder head 2, to provide a space on the front and rear sides of the EGR cooler 27. This enables cool air to flow around the EGR cooler 27, thus increasing the cooling efficiency of the EGR cooler 27.

In the EGR cooler coupling base **33**, the downstream coolant passage **38** is disposed above the upstream EGR gas relay fluid passage **31**. In the EGR cooler coupling base **34**, the downstream EGR gas relay fluid passage **32** is disposed above the upstream coolant passage **39**. A coolant inlet of the downstream coolant passage **38** and an EGR gas inlet of the downstream EGR gas relay fluid passage **32** are disposed at the same height. A coolant outlet of the upstream coolant passage **39** and an EGR gas outlet of the downstream EGR gas relay fluid passage **32** are disposed at the same height.

Since the EGR gas relay fluid passages **31**, **32** and the coolant passages **38**, **39** are provided in the EGR cooler coupling bases **33**, **34** protruding at a distance from each other, a mutual influence between thermal deformations of the EGR cooler coupling bases **33**, **34** is relieved. In the EGR cooler coupling bases **33**, **34**, the EGR gas flowing in the EGR gas relay fluid passages **31**, **32** is cooled by the coolant flowing in the coolant passages **38**, **39**, so that thermal deformations of the EGR cooler coupling bases **33**, **34** are suppressed. In addition, the up-down positional relationship of the EGR gas relay fluid passages **31**, **32** and the coolant passages **38**, **39** in one of the EGR cooler coupling bases **33**, **34** is reverse to that in the other of the EGR cooler coupling bases **33**, **34**. As a result, heat distributions in the respective EGR cooler coupling bases **33**, **34** are in opposite directions with respect to the up-down direction, which can reduce an influence of thermal deformation in the height direction in the cylinder head **2**.

An outer peripheral wall of the cylinder head **2** stands upward at a peripheral edge of the upper surface of the cylinder head **2**, to provide a spacer **46** which is coupled to a peripheral edge of a lower surface of the head cover **18**. The spacer **46** has, in a right surface thereof, a plurality of openings **47**. Fuel pipes **48** which couple injectors (not shown) provided in the cylinder head **2** to the common rail **16** pass through the openings **47**. Since the spacer **46** integrated with the cylinder head **2** is disposed above the cylinder head **2**, the rigidity of the cylinder head **2** is increased, which can reduce distortion of the cylinder head **2** itself and also can allow component parts coupled to the cylinder head **2** to be supported with a high rigidity.

A configuration of the EGR device **24** will now be described with reference to FIG. **9** to FIG. **11**, FIG. **14**, FIG. **15**, and FIG. **17** to FIG. **19**. As shown in FIG. **9** to FIG. **11**, FIG. **14**, FIG. **15**, and FIG. **17** to FIG. **19**, the EGR device **24** includes the collector (main body case) **25** that mixes fresh air with an EGR gas, and supplies a mixture to the intake manifold **3**. The intake manifold **3** and the intake throttle member **26** for taking fresh air in are connected in communication with each other via the collector **25**. The EGR valve member **29** which leads to an outlet side of the recirculation exhaust gas tube **28** is connected in communication with the collector **25**.

In the collector **25**, a fresh air flow direction and an EGR gas flow direction cross each other perpendicularly or with an obtuse angle, and a direction in which a mixed gas of the EGR gas and the fresh air is taken into the intake manifold **3** intersects each of the fresh air flow direction and the EGR gas flow direction. A fresh air inlet **81** to which the fresh air is supplied is opened in one of front and rear surfaces of the collector **25**, whereas an EGR gas inlet **82** to which the EGR gas is supplied is opened in the other of the front and rear surfaces of the collector **25**. The intake outlet **83** which is coupled to the intake manifold **3** is opened in a left surface of the collector **25**. The EGR gas inlet **82** and the intake

outlet **83** are disposed at the same height, and the fresh air inlet **81** and the EGR gas inlet **82** are disposed at different heights.

In the collector **25**, fresh air taken from the intake throttle member **26** into the fresh air inlet **81** flows in the front-rear direction and then in the up-down direction while curving in an L-shape, whereas an EGR gas taken from the EGR valve member **29** into the EGR gas inlet **82** flows obliquely upward. As a result, the EGR gas flows in toward a flow of the fresh air, which facilitates mixing of the EGR gas with the fresh air. The mixed gas of the fresh air and the EGR gas flows in the up-down direction and then in the left-right direction while curving in an L-shape, to flow into the intake manifold **3** through the intake outlet **83**. A direction in which the mixed gas is emitted intersects not only the directions in which the fresh air and the EGR gas are taken in but also the directions in which the fresh air and the EGR gas flow within the collector **25**. Consequently, a distribution of mixture of the EGR gas with the fresh air can be made uniform.

In the collector **25**, as described above, the EGR gas flow direction is at an angle of 90° or more relative to the fresh air flow direction, and the fresh air flow and the EGR gas flow intersect each other, so that a distribution of mixture of the EGR gas with the fresh air can be made uniform, and an uneven flow of the EGR gas in the intake manifold **3** can be suppressed. As a result, a concentration of the intake EGR gas supplied to each of the plurality of intake fluid passages **36** of the cylinder head **2** can be made uniform. Thus, a variation in combustion action among cylinders of the diesel engine **1** can be suppressed. Consequently, generation of brack smoke is suppressed, and the amount of NOx can be reduced while a good combustion state of the diesel engine **1** is maintained. That is, purifying (cleaning) the exhaust gas by a recirculation flow of the EGR gas can be achieved without causing a misfire in a specific cylinder.

The collector **25** includes an upper case (first case) **84** with the fresh air inlet **81** and a lower case (second case) **85** with the EGR gas inlet **82** and the intake outlet **83** being coupled to each other. Since the collector **25** is divisible in the up-down direction into the upper case **84** and the lower case **85**, a mixed fluid passage where the EGR gas flow and the fresh air flow intersect each other at an angle of 90° or more can be easily formed in the collector **25**. It therefore is possible that the collector **25** is formed as a casting with a high rigidity, and moreover, weight reduction of the collector **25** can be obtained by forming the collector **25** as an aluminium-based casting product.

The upper case **84** is provided therein with a downstream EGR gas fluid passage (first EGR gas fluid passage) **86a** which is a part of the EGR gas fluid passage **86** where the EGR gas flows and a mixing chamber **87** in which the fresh air and the EGR gas are mixed. The lower case **85** is provided therein with an upstream EGR gas fluid passage (second EGR gas fluid passage) **86b** through which the downstream EGR gas fluid passage **86a** is in communication with the EGR gas inlet **82** and a mixed gas fluid passage **88** through which a mixed gas obtained by mixing the fresh air with the EGR gas is supplied from the mixing chamber **87** to the intake manifold **3**.

The EGR gas inlet **82** is disposed in the lower case **85** while the fresh air inlet **81** and the mixing chamber **87** are disposed in the upper case **84**. In the mixing chamber **87**, therefore, the fresh air flowing from the fresh air inlet **81** and the EGR gas flowing from the lower case **85** intersect each other, so that the fresh air and the EGR gas can be efficiently mixed. In addition, the intake outlet **83** is disposed in the lower case **85**, and the fresh air having entered the upper

case **84** tends to flow toward the lower case **85**. As a result, mixing of the EGR gas flowing toward the upper case **84** with the fresh air is made uniform. Furthermore, each of the EGR gas fluid passage **86**, the mixing chamber **87**, and the mixed gas fluid passage **88** can be compactly configured within the collector **25**, and thus the collector **25** can be downsized.

In a plan view, the downstream EGR gas fluid passage **86a** is coupled with an offset to a side surface (right side surface) of the mixing chamber **87** opposite to a side surface (left side surface) thereof having the intake outlet **83** relative to a central axis of the mixing chamber **87**, and the downstream EGR gas fluid passage **86a** and the upstream EGR gas fluid passage **86b** are in communication with each other so that the EGR gas fluid passage **86** is formed in a spiral manner. The EGR gas fluid passage **86** composed of the downstream EGR gas fluid passage **86a** and the upstream EGR gas fluid passage **86b** has a bent shape curved toward the side (right side) opposite to the intake outlet **83** in a plan view. A bottom of the upstream EGR gas fluid passage **86b** is constituted by a slope (a slope inclined upward toward the rear) extending from the EGR gas inlet **82** toward the upper case **84**.

A portion of the mixing chamber **87** that is in communication with the EGR gas fluid passage **86** is on the side opposite to the intake outlet **83**. The EGR gas flowing into the mixing chamber **87**, therefore, reaches the intake outlet **83** while being guided by a fresh air flow, which allows the EGR gas to be uniformly mixed with the fresh air. The EGR gas flowing from the EGR gas fluid passage **86** into the mixing chamber **87** flows in a direction against the direction from the mixing chamber **87** toward the mixed gas fluid passage **88**. This causes the fresh air and the EGR gas to collide with each other while flowing within the mixing chamber **87**. Accordingly, the EGR gas is smoothly mixed with the fresh air.

Since the EGR gas flows along the EGR gas fluid passage **86** having a spiral shape, the EGR gas creates a swirling flow having a clockwise vortex when flowing into the mixing chamber **87**. Such a turbulent EGR gas flows in a direction against the fresh air gas flow. Thus, simultaneously with flowing into the mixing chamber **87**, the EGR gas is smoothly mixed with the fresh air flowing within the mixing chamber **87**. In the collector **25**, therefore, the fresh air and the EGR gas can be efficiently mixed (the EGR gas can be smoothly dispersed in the mixed gas) by agitation before they are fed to the intake manifold **3**, so that a variation (unevenness) in the gas mixing state within the collector **25** can be suppressed more reliably. As a result, a mixed gas having less unevenness can be distributed to the respective cylinders of the diesel engine **1**, and a variation in the EGR gas amount among the cylinders can be suppressed. Accordingly, it is possible to suppress generation of brack smoke, and to reduce the amount of NOx while maintaining a good combustion state of the diesel engine **1**. In addition, the EGR gas fluid passage **86** having a spiral shape gives sufficient swirling properties to the EGR gas flowing into the mixing chamber **87**. Thus, the collector **25** can be shaped with a shortened length in the front-rear direction.

A lower surface flange **84a** of the upper case **84** and an upper surface flange **85a** of the lower case **85** are fastened with bolts, to form the collector **25** having openings (the fresh air inlet **81**, the EGR gas inlet **82**, and the intake outlet **83**) in three directions (toward the front, rear, and left). The upper case **84** has a rear surface flange **84b** in which the fresh air inlet **81** is opened, and a fresh air outlet of the intake throttle member **26** is fastened to the rear surface flange **84b**

with bolts. The intake throttle member **26** adjusts the degree of opening of an intake valve (butterfly valve) **26a** provided therein, to thereby adjust the amount of fresh air supply to the collector **25**.

The lower case **85** has a front surface flange **85b** in which the EGR gas inlet **82** is opened, and an EGR gas outlet of the EGR valve member **29** is fastened with bolts to the front surface flange **85b** with interposition of a relay flange **89** having a rectangular pipe shape. The EGR valve member **29** adjusts the degree of opening of an EGR valve (not shown) provided therein, to thereby adjust the amount of EGR gas supply to the collector **25**. A reed valve **90** inserted in the EGR gas inlet **82** is fixed inside the front surface flange **85b** of the lower case **85**. The relay flange (spacer) **89** which is fastened to the front surface flange **85b** with bolts covers the front side of the reed valve **90**. As a result, the collector **25** is provided therein with the reed valve **90** disposed in a portion of the EGR gas fluid passage **86**, the portion being on the EGR gas inlet **82** side.

The relay flange **89** has, in its rear surface coupled to the collector **25**, an EGR gas outlet **89a** which is in communication with the EGR gas inlet **82**. The relay flange **89** has a front surface from which valve coupling bases **89b**, **89c** to be coupled to the EGR valve member **29** protrude. Openings of the valve coupling bases **89b**, **89c** are in communication with the EGR gas outlet of the EGR valve member **29**. In the relay flange **89**, the EGR gas is merged at EGR gas inlets of the upper and lower valve coupling bases **89b**, **89c**, and then is caused to flow from the EGR gas inlet **82** into the EGR gas fluid passage **86** provided inside the collector **25** via the reed valve **90**.

The EGR valve member **29** is configured such that: a valve body **29e** has an EGR gas fluid passage **29f** in which an EGR valve (not shown) is disposed; an actuator **29d** for adjusting the degree of opening of the EGR valve is disposed above the valve body **29e**; the EGR valve member **29** has its longitudinal direction in parallel to the up-down direction; and the EGR valve member **29** is coupled to the front side of the collector **25** with interposition of the relay flange **89**. The EGR valve member **29** has, in a rear surface of the valve body **29e** which is arranged lower, outlet side flanges **29a**, **29b** to be coupled respectively to the valve coupling bases **89b**, **89c** of the relay flange **89**. The outlet side flanges **29a**, **29b** are arranged one above the other. The EGR valve member **29** also has, in its front surface, an inlet side flange **29c** having an EGR gas inlet that is in communication with the EGR gas outlet of the recirculation exhaust gas tube **28**.

The EGR valve member **29** is configured such that: after an EGR gas cooled by the EGR cooler **27** flows into the EGR gas inlet of the inlet side flange **29c** through the downstream EGR gas relay fluid passage **32** of the EGR cooler coupling base **34** and the recirculation exhaust gas tube **28**, the EGR gas is distributed to upper and lower parts via the EGR gas fluid passage **29f** of the valve body **29e**. The EGR gas flow distributed to upper and lower parts through the EGR gas fluid passage **29f** is then subjected to a flow rate adjustment by the EGR valve, and then enters the relay flange **89** through the EGR gas outlets of the upper and lower outlet side flanges **29a**, **29b**.

The recirculation exhaust gas tube **28** includes a gas pipe portion **28a** and a rib **28b**, the gas pipe portion **28a** being bent to have an L-shape in a plan view, the rib **28b** having a flat-plate shape protruding from an inner peripheral side of an outer wall of the gas pipe portion **28a**. The recirculation exhaust gas tube **28** has, at one end (rear end) of the gas pipe portion **28a**, an outlet side flange **28c** to be coupled to the inlet side flange **29c** of the EGR valve member **29**, and also

15

has, at the other end (left end) of the gas pipe portion **28a**, an inlet side flange **28d** to be coupled to the right surface of the EGR cooler coupling base **34**. The recirculation exhaust gas tube **28** further has, in an upper surface of a bent portion of the gas pipe portion **28a**, a sensor attachment base **28e** to which an EGR gas temperature sensor is attached.

In the EGR device **24**, the collector **25** can be configured with a shortened length, and therefore the distance between the EGR valve member **29** and the intake throttle member **26** can be shortened, which enables the length of the EGR device **24** in the front-rear direction to be shortened. In the EGR valve member **29**, the actuator **29d** is disposed on the upper side. It therefore is possible that topmost portions of the EGR valve member **29**, the collector **25**, and the intake throttle member **26** are at the same height. This can lower the height of the EGR device **24** in the up-down direction, and also can narrow the width of the EGR device **24** in the left-right direction. Since the EGR device **24** can be configured compactly, coupling the EGR device **24** to the right side of the cylinder head **2** integrated with the intake manifold **3** can be easily implemented merely by adjusting the recirculation exhaust gas tube **28**. In addition, such a configuration contributes to downsizing of the diesel engine **1**.

The recirculation exhaust gas tube **28** has the flat-plate rib **28b** that is coupled so as to connect the opposite ends of the gas pipe portion **28a**. This gives a high rigidity to the recirculation exhaust gas tube **28**, and also increases a strength with which the front end side of the EGR device **24** is supported on the cylinder head **2**. In addition, the recirculation exhaust gas tube **28** has the flat-plate rib **28b** that is disposed along an EGR gas fluid passage **28f** provided inside the gas pipe portion **28a**. Due to the rib **28b**, the gas pipe portion **28a** has a wide heat dissipation area, which increases the effect of cooling the EGR gas flowing in the EGR gas fluid passage **28f**. This contributes to cooling a mixed gas prepared in the EGR device **24**, and exerts an effect that reduction in the amount of NOx generated from the mixed gas can be easily kept in a proper state.

A configuration of the EGR cooler **27** will now be described with reference to FIG. **9** to FIG. **11**, FIG. **13** to FIG. **16**, and FIG. **20** to FIG. **21**. As shown in FIG. **9** to FIG. **11**, FIG. **13** to FIG. **16**, and FIG. **20** to FIG. **21**, the EGR cooler **27** includes a heat exchanger **91** and a pair of left and right flange portions **92**, **93**. The heat exchanger **91** has a coolant passage and an EGR gas fluid passage alternately stacked. The pair of left and right flange portions **92**, **93** are disposed in left and right end portions of one side surface of the heat exchanger **91**. The coolant outlet **94** is disposed in one of the left and right flange portions **92**, **93**, while the coolant inlet **95** is disposed in the other of the left and right flange portions **92**, **93**. The EGR gas inlet **96** is disposed in one of the left and right flange portions **92**, **93**, while the EGR gas outlet **97** is disposed in the other of the left and right flange portions **92**, **93**. The left and right flange portions **92**, **93** are coupled to the front surface of the cylinder head **2**, so that the EGR cooler **27** is fixed to the cylinder head **2**.

Since each of the pair of left and right flange portions **92**, **93** has a coolant opening and an EGR gas opening, it is possible that the flange portions **92**, **93** are made from a common member, and moreover material costs of the flange portions **92**, **93** can be suppressed. The flange portions **92**, **93** are formed by a flat plate being bored to have through holes **100** to **103** corresponding to the coolant and the EGR gas, the flat plate being coupled to the cylinder head **2**. Thus, forming the flange portions **92**, **93** in the EGR cooler **27** is

16

easy. In addition, a coupling portion where the flange portions **92**, **93** are coupled to the heat exchanger **91** can be minimized, so that the amount of heat transfer from the cylinder head **2** to the heat exchanger **91** can be reduced, which increases the effect of cooling the EGR gas by the heat exchanger **91**.

Since the EGR cooler **27** has the flange portions **92**, **93** protruding from the rear surface of the heat exchanger **91**, a space is formed between the heat exchanger **91** and the cylinder head **2**. As a result, the EGR cooler **27** is in a state where a wide area of the front and rear surfaces of the heat exchanger **91** is exposed to outdoor air. Heat dissipation occurs in the heat exchanger **91**, too. Thus, the effect of cooling the EGR gas by the EGR cooler **27** is increased. This configuration can reduce the degree of stacking in the heat exchanger **91** as compared to a configuration in which the rear surface and the front surface of the heat exchanger **91** are attached. The length of the EGR cooler **27** in the front-direction can be shorted, and thus the diesel engine **1** can be downsized.

The left flange portion **92** has the coolant outlet **94** and the EGR gas inlet **96**, while the right flange portion **93** has the coolant inlet **95** and the EGR gas outlet **97**. In the left flange portion **92**, the coolant outlet **94** is disposed above the EGR gas inlet **96**, while in the right flange portion **93**, the EGR gas outlet **97** is disposed above the coolant inlet **95**. The coolant outlet **94** and the EGR gas outlet **97** are disposed at the same height, while the coolant inlet **95** and the EGR gas inlet **96** are disposed at the same height.

The left and right flange portions **92**, **93** of the EGR cooler **27** are coupled respectively to the EGR cooler coupling bases **33**, **34** protruding from the front surface of the cylinder head **2**. The upstream EGR gas relay fluid passage **31** and the downstream coolant passage **38** of the left EGR cooler coupling base **33** are in communication with the EGR gas inlet **96** and the coolant outlet **94** of the left flange portion **92**, respectively. The downstream EGR gas relay fluid passage **32** and the upstream coolant passage **39** of the right EGR cooler coupling base **34** are in communication with the EGR gas outlet **97** and the coolant inlet **95** of the right flange portion **93**, respectively.

The EGR gas relay fluid passages **31**, **32** and the coolant passages **38**, **39** are provided in the coupling bases **33**, **34** to which the flange portions **92**, **93** of the EGR cooler **27** are coupled, and are in communication with the EGR gas inlet and outlet **96**, **97** and the coolant outlet and inlet **94**, **95** of the flange portions **92**, **93**. It is not necessary that coolant piping and EGR gas piping are disposed between the EGR cooler **27** and the cylinder head **2**. Accordingly, a sealability can be given to a coupling portion where the EGR cooler **27** and the cylinder head **2** are coupled to each other without any influence of, for example, extension and contraction of piping caused by the EGR gas or the coolant. In addition, the EGR cooler **27** is given an enhanced resistance against external fluctuation factors such as heat and vibration, and can be compactly installed in the cylinder head **2**.

The coolant outlet **94** is disposed above the EGR gas inlet **96** in the flange portion **92**, while the EGR gas outlet **97** is disposed above the coolant inlet **95** in the flange portion **93**. Thus, the flange portions **92**, **93** having identical shapes with their postures mutually upside-down are attached to the heat exchanger **91**. This can reduce the number of types of component parts included in the EGR cooler **27**, thus improving an assemblability of the EGR cooler **27** and reducing costs of the component parts.

The flange portion **92** is provided with the coolant outlet **94** and the EGR gas inlet **96** through which a coolant or an

EGR gas having a large quantity of heat passes, while the flange portion **93** is provided with the coolant inlet **95** and the EGR gas outlet **97** through which a coolant or an EGR gas having a small quantity of heat passes. Accordingly, distortion caused by thermal deformation of each of the flange portions **92**, **93** can be suppressed. In addition, the flange portions **92**, **93** are configured as separate members whose thermal deformation is less influential to each other, and therefore damage and breakdown of the EGR cooler **27** can be prevented.

In the EGR cooler **27**, the coolant outlet **94** and the coolant inlet **95** are disposed at diagonal positions, and the EGR gas inlet **96** and the EGR gas outlet **97** are disposed at diagonal positions in a rear view. Since EGR gases having different quantities of heat and coolants having different quantities of heat are respectively supplied or discharged at diagonal positions, thermal deformations of coupling portions where the EGR cooler **27** is coupled to the cylinder head **2** can be mutually relieved, so that deflection or slackness of the coupling portions can be suppressed. Accordingly, leakage of an EGR gas or a coolant in the EGR cooler **27** and in the cylinder head **2** can be prevented, and moreover a decrease in the coupling strength can be prevented.

A plate-shaped gasket **98** is sandwiched between the cylinder head **2** and the flange portions **92**, **93** so as to extend across the left and right flange portions **92**, **93**. A coolant inlet and a coolant outlet of the cylinder head **2**, which are respectively in communication with the coolant outlet **94** and the coolant inlet **95** of the flange portions **92**, **93**, have O-rings **99** embedded therein, the O-rings **99** being ring-shaped seal members. The O-rings **99** are covered with the flange portions **92**, **93**.

Since the flange portions **92**, **93** configured as separate members are coupled to the coupling bases **33**, **34** of the cylinder head **2** with the gasket **98** interposed therebetween, a tension is exerted on the gasket **98** due to thermal deformation of the coupling portion coupled to the cylinder head **2**. This enhances a sealability (hermetic sealing performance) of the gasket **98** in a coupling portion of each of the EGR gas inlet **96** and the EGR gas outlet **97**. Thus, leakage of an EGR gas flowing from one to the other between the cylinder head **2** and the EGR cooler **27** can be prevented. The O-rings **99** are embedded in spaces defined by rear end surfaces of the flange portions **92**, **93** and the coolant inlet and the coolant outlet of the coupling bases **33**, **34** of the cylinder head **2**. When a coolant flows, therefore, the coolant is in contact with the O-rings **99** in communication portions where the coupling bases **33**, **34** are in communication with the flange portions **92**, **93**. Thus, a sealability (hermetic sealing performance) of the coupling portions of the coolant outlet and inlet **94**, **95** can be obtained. Accordingly, even though the EGR cooler **27** where a liquid and a gas enter and exit is coupled to the cylinder head **2**, a sealability for each of the liquid and the gas can be obtained, so that leakage of each of the EGR gas and the coolant can be prevented.

An outer peripheral portion of each of the flange portions **92**, **93** is bored to have through holes **100** for bolt fastening, at outer positions. Specifically, the left flange portion **92** has five through holes **100** disposed in its upper, lower, and left sides, and the right flange portion **93** has five through holes **100** disposed in its upper, lower, and right sides. Since the left flange portion **92** has the through holes **100** disposed above the coolant outlet **94**, below the EGR gas inlet **96**, and to the left of a portion between the coolant outlet **94** and the EGR gas inlet **96**, a sealability of the coolant outlet **94** and the EGR gas inlet **96** can be exerted when the left flange

portion **92** is fastened to the coupling base **33** of the cylinder head **2** with bolts. Likewise, since the right flange portion **93** has the through holes **100** disposed below the coolant inlet **95**, above the EGR gas outlet **97**, and to the right of a portion between the coolant inlet **95** and the EGR gas outlet **97**, a sealability of the coolant inlet **95** and the EGR gas outlet **97** can be exerted when the right flange portion **93** is fastened to the coupling base **34** of the cylinder head **2** with bolts.

The gasket **98** is constituted by a lamination of two plates **98a**, **98b** each having through holes **101** to **103**. The EGR gas passes through the through holes (EGR gas through holes) **101**. The coolant passes through the through holes (coolant through holes) **102**. Fastening bolts are inserted into the through holes (bolt through holes) **103**. The gasket **98** has such a shape that an inner peripheral edge at the EGR gas through hole **101** is branched so as to be warped in the front-rear direction and is configured such that the open areas of the coolant through holes **102** are larger than the open areas of the coolant outlet and inlet **94**, **95**.

In the gasket **98**, the front plate **98a** has its inner peripheral edge at the EGR gas through hole **101** being warped frontward, while the rear plate **98b** has its inner peripheral edge at the EGR gas through hole **101** being warped rearward. The front plate **98a** and the rear plate **98b** are bonded by welding, so that the inner peripheral edge at the EGR gas through hole **101** has a Y-shaped cross-section. Since the inner peripheral edge at the EGR gas through hole **101** is warped in the front-rear direction, front and rear surfaces of the inner peripheral edge at the EGR gas through hole **101** can be in tight contact with end surfaces of the coupling bases **33**, **34** and the flange portions **92**, **93**. Accordingly, a sufficient airtightness can be obtained.

The gasket **98** is configured such that the openings of the coolant through holes **102** is larger than those of the coolant outlet and inlet **94**, **95**. Thus, the O-rings **99** are inserted in the coolant through holes **102**. Communication portions where the coolant outlet and inlet **94**, **95** of the flange portions **92**, **93** are in communication with the coolant relay fluid passages **38,39** of the coupling bases **33**, **34** are hermetically sealed by the O-rings **99** fitted in the coolant through holes **102** of the gasket **98**.

The coupling bases **33**, **34** of the cylinder head **2** have the coolant outlet and inlet **94**, **95** opened with steps, and thereby the openings of the coolant outlet and inlet **94**, **95** are given larger diameters than the fluid passage diameters of the coolant relay fluid passages **38**, **39** formed inside the coupling bases **33**, **34**. The O-rings **99** disposed to the coolant outlet and inlet **94**, **95** of the coupling bases **33**, **34** are fitted on the outer circumferential sides of the coolant relay fluid passages **38**, **39**. The O-rings **99** are inserted in the gasket **98**, and also fitted in the step portions of the coolant outlet and inlet **94**, **95** in the coupling bases **33**, **34**. Thereby, the O-rings **99** are sandwiched between the coupling bases **33**, **34** and the flange portions **92**, **93**. When a coolant passes inside the O-rings **99** made of an elastic material, the O-rings **99** are deformed to expand outward and come into tight contact with the coupling bases **33**, **34** and the flange portions **92**, **93**, thus providing a sealability for the coolant.

The ring-shaped O-ring **99** has its inner circumferential portion bulging frontward and rearward. A coolant passing through the inner circumferential portion of the O-ring **99** pushes the inner circumferential portion, so that its front and rear edges are deformed to protrude frontward and rearward. This brings the inner circumferential portion of the O-ring **99** into tight contact with the coupling bases **33**, **34** and the flange portions **92**, **93**. Thus, a sealability for the coolant can

be enhanced in the coupling portion where the cylinder head **2** is coupled to the EGR cooler **27**.

The ring-shaped O-ring **99** whose inner circumferential portion is bulged frontward and rearward is shaped such that its inner circumferential surface has a recessed portion. The inner circumferential surface of the O-ring **99** is warped frontward and rearward so as to have a Y-shaped cross-section. A coolant passing through the inner circumferential portion of the O-ring **99** pushes the inner circumferential portion, so that its front and rear edges are further protruded frontward and rearward, to increase the degree of tight contact of the inner circumferential portion of the O-ring **99** with the coupling bases **33**, **34** and the flange portions **92**, **93**. Accordingly, a sealability for the coolant can be enhanced in the coupling portion where the cylinder head **2** is coupled to the EGR cooler **27**.

A configuration of the two-stage turbocharger **30** will now be described with reference to FIG. **22** to FIG. **27**, etc. As shown in FIG. **22** to FIG. **27**, the two-stage turbocharger **30** uses fluid energy of an exhaust gas discharged from the exhaust manifold **4**, to compress fresh air which then flows into the intake manifold **3** of the cylinder head **2**. The two-stage turbocharger **30** includes the high-pressure turbocharger **51** coupled to the exhaust manifold **4**, and the low-pressure turbocharger **52** coupled to the high-pressure turbocharger **51**.

The high-pressure turbocharger **51** is disposed on the left lateral side of the exhaust manifold **4**, while the low-pressure turbocharger **52** is disposed above the exhaust manifold **4**. The high-pressure turbocharger **51** with a low capacity is disposed opposed to the exhaust manifold **4**, while the low-pressure turbocharger **52** with a high capacity is disposed above the exhaust manifold **4** which is installed to the cylinder head **2** so as to protrude laterally leftward. This enables the exhaust manifold **4** and the two-stage turbocharger **30** to be compactly arranged in a space existing on the left lateral side of the cylinder head **2**, and also enables a topmost portion of the two-stage turbocharger **30** to be positioned lower than a topmost portion of the diesel engine **1**. This can contribute to downsizing of the diesel engine **1**. In addition, the low-pressure turbocharger **52** can be disposed close to the cylinder head **2**, and thus the two-stage turbocharger **30** can be fixed with a high rigidity.

The high-pressure turbocharger **51** includes the high-pressure turbine **53** that is in communication with the exhaust gas outlet **44** of the exhaust manifold **4**, and the high-pressure compressor **54** that supplies compressed air to the intake manifold **3**. The high-pressure compressor **54** is in communication with the fresh air inlet **81** (see FIG. **17**, etc.) of the intake throttle member **26** via an intercooler (not shown), and thereby supplies compressed air to the intake manifold **3** via the EGR device **24**. The low-pressure turbocharger **52** includes the low-pressure turbine **55** whose exhaust gas inlet is in communication with an exhaust gas outlet of the high-pressure turbine **53** via an exhaust relay pipe, and the low-pressure compressor **56** whose fresh air outlet is in communication with a fresh air inlet of the high-pressure compressor **54** via a fresh air relay pipe. The low-pressure compressor **56** is disposed above the high-pressure turbine **53**, the high-pressure compressor **54** is disposed on one of the front and rear sides relative to the high-pressure turbine **53**, and the low-pressure turbine **55** is disposed on the other of the front and rear sides relative to the low-pressure compressor **56**.

The exhaust gas outlet **44** of the exhaust manifold **4**, which discharges an exhaust gas, is opened toward one of the left and right lateral sides. The exhaust gas inlet **57** of the

high-pressure turbine **53** is opened toward the exhaust manifold **4**, and the exhaust gas outlet **58** of the high-pressure turbine **53** is opened frontward. The exhaust gas inlet **60** of the low-pressure turbine **55** is opened downward, and the exhaust gas outlet **61** of the low-pressure turbine **55** is opened frontward.

The exhaust gas outlet **44** of the exhaust manifold **4** and the exhaust gas inlet **57** of the high-pressure turbine **53**, which are opposed to each other, are flange-coupled with bolts, and thus the high-pressure turbocharger **51** is fixed on the left lateral side of the exhaust manifold **4**. The exhaust gas outlet **58** of the high-pressure turbine **53** is flange-coupled to one end (rear end) of the L-shaped high-pressure exhaust gas tube **59** (exhaust relay pipe) with bolts. The exhaust gas inlet **60** of the low-pressure turbine **55** is flange-coupled to the other end (upper end) of the high-pressure exhaust gas tube **59** with bolts. The low-pressure turbocharger **52** is fixed on the upper side of the high-pressure turbocharger **51**.

The high-pressure turbine **53** is flange-coupled to the exhaust manifold **4** so that the high-pressure turbocharger **51** is supported with a high rigidity, and in this condition, the low-pressure turbine **55** is flange-coupled to an upper surface of the high-pressure exhaust gas tube **59** that is flange-coupled to the front side of the high-pressure turbocharger **51**. Thereby, the low-pressure turbocharger **52** can be supported from below by the high-pressure turbocharger **51**. Since the low-pressure turbocharger **52** is installed close to a position above the exhaust manifold **4**, the center of gravity of the low-pressure turbocharger **52** is in the vicinity of a position above the position where the exhaust manifold **4** is coupled to the high-pressure turbocharger **51**. Accordingly, the two-stage turbocharger **30** can be compactly supported with a high rigidity in the vicinity of the diesel engine **1**.

The high-pressure compressor **54** has a fresh air inlet port **63** (fresh air inlet) opened rearward, and has a fresh air supply port **64** (fresh air outlet) opened downward. The low-pressure compressor **56** has a fresh air inlet port **66** (fresh air inlet) opened rearward, and has a fresh air supply port **67** (fresh air outlet) protruding from the left lateral side and then directed downward. The U-shaped low-pressure fresh air passage pipe **65** (fresh air relay pipe) has one end thereof fixed to the fresh air inlet port **63** (fresh air inlet) of the high-pressure compressor **54**, and has the other end thereof coupled to the fresh air supply port **67** (fresh air outlet) of the low-pressure compressor **56**.

The high-pressure compressor **54** and the low-pressure compressor **56** are coupled by the U-shaped low-pressure fresh air passage pipe **65** disposed at the rear, and a front portion of the low-pressure turbocharger **52** can be fixed to the high-pressure turbocharger **51** which is supported with a high rigidity by the exhaust manifold **4**. The fresh air inlet port **66** and the fresh air supply port **67** of the low-pressure compressor **56** are extended in the same direction (rearward), and can be easily coupled to the air supply pipe **62** which is in communication with an air cleaner (not shown) and to the low-pressure fresh air passage pipe **65**, respectively. This configuration can enhance a workability in assembling.

The low-pressure fresh air passage pipe **65** includes a metal pipe **65a** and a resin pipe **65b**. The metal pipe **65a** has its one end flange-coupled and bolt-fastened to the fresh air inlet port **66** of the high-pressure compressor **54**. The resin pipe **65b** allows the other end of the metal pipe **65a** to communicate with the fresh air supply port **67** of the low-pressure compressor **56**. Thereby, in the low-pressure

fresh air passage pipe **65**, the metal pipe **65a** is fixed to the high-pressure compressor **54** with a high rigidity, and the resin pipe **65b** allows the low-pressure compressor **56** and the metal pipe **65a** to communicate with each other while lessening an assembling error therebetween.

The fresh air supply port **67** of the low-pressure compressor **56** protrudes laterally leftward from a left surface of the low-pressure compressor **56**, and then is directed upward toward the rear. This configuration enables the low-pressure fresh air passage pipe **65** (metal pipe **65a**) to be bent with a large curvature. As a result, generation of a turbulent flow in the low-pressure fresh air passage pipe **65** can be suppressed, so that the compressed air discharged from the low-pressure compressor **56** can be smoothly supplied to the high-pressure compressor **54**.

The blow-by gas recirculation device **19** for taking a blow-by gas in is installed above the cylinder head **2**. The blow-by gas recirculation device **19** is placed on and fixed to the upper surface of the head cover **18** that covers the upper surface of the cylinder head **2**. A blow-by gas outlet **70** disposed at the rear of the blow-by gas recirculation device **19** is coupled to the air supply pipe **62** through the recirculation hose **68**, the air supply pipe **62** being coupled to the fresh air inlet port **66** (fresh air inlet) of the low-pressure compressor **56**. The air supply pipe **62** is disposed between the low-pressure fresh air passage pipe **65** (fresh air relay pipe) and the cylinder head **2**.

The air supply pipe **62** is coupled to the rear side of the low-pressure turbocharger **52** which is an upper component of the two-stage turbocharger **30**, and is disposed close to the cylinder head **2**. Thus, the distance between the air supply pipe **62** and the blow-by gas recirculation device **19** disposed above the cylinder head **2** can be shortened. This makes it possible to shorten the recirculation hose **68** to prevent the inside of the recirculation hose **68** from being frozen under low-temperature environments. Since the air supply pipe **62** is disposed in a space surrounded by the low-pressure fresh air passage pipe **65** and the cylinder head **2**, the air supply pipe **62** can be prevented from being damaged by an external force which may be applied in a coupling portion coupled to a resin pipe which is connected to the air cleaner (not shown).

The fresh air supply port **64** of the high-pressure turbocharger **51**, which is opened downward, protrudes from a portion of a lower surface of the high-pressure compressor **54**, the portion being on the cylinder head **2** side. The high-pressure compressor **54** is coupled to the high-pressure fresh air passage pipe **71** which is in communication with the intercooler (not shown). The high-pressure compressor **54** supplies compressed air to the intercooler through the high-pressure fresh air passage pipe **71**. The coolant inlet pipe **22** which is opened laterally leftward is provided below the high-pressure compressor **54**. The high-pressure fresh air passage pipe **71** as well as coolant piping which is in communication with the radiator (not shown) is arranged so as to extend to a rear portion of the left surface of the cylinder block **6**, and thereby the high-pressure fresh air passage pipe **71** can be coupled to the coolant inlet pipe **22** and to the fresh air supply port **64** of the high-pressure compressor **54**. As a result, pipe routing for the coolant piping and the high-pressure fresh air passage pipe **71** can be collected, which can simplify a piping structure in a main machine equipped with the diesel engine **1** and also can make an assembling work and a maintenance work easy.

In the diesel engine **1**, the coolant outlet pipe **23**, the air supply pipe **62**, and the intake throttle member **26** are disposed above the cylinder head **2** and on the cooling fan

9 side. In the main machine equipped with the diesel engine **1**, therefore, when the radiator (not shown), the air cleaner (not shown), and the intercooler (not shown) which use cooling air of the cooling fan **9** are disposed on the rear side of the cooling fan **9**, coolant piping connected to the radiator and fresh air piping communicating with the air cleaner and the intercooler can be shortened, and moreover works for connecting such piping can be performed together. As a result, an assembling work and a maintenance work in the main machine can be performed with ease, and in addition, component parts to be coupled to the diesel engine **1** can be efficiently arranged in the main machine.

The exhaust gas outlet **58** of the high-pressure turbine **53** is provided with a turbine discharge hole **58a**, a bypass hole **58b**, and a wastegate valve **69**. The turbine discharge hole **58a** discharges an exhaust gas which rotates a turbine wheel (not shown). The bypass hole **58b** allows the exhaust gas inlet **57** and the exhaust gas outlet **58** to communicate with each other. The wastegate valve **69** opens and closes the bypass hole **58b**. Arranging the turbine discharge hole **58a** and the bypass hole **58b** side-by-side in the exhaust gas outlet **58** of the high-pressure turbine **53** enables whether to perform a compression operation by the high-pressure turbocharger **51** to be set in accordance with a rotational frequency of the diesel engine **1**. Accordingly, with efficient use of exhaust energy, the two-stage turbocharger **30** can stabilize the amount of fresh air to be supplied to the combustion chamber, and can reduce the amount of brack smoke discharge while increasing an engine output.

When the bypass hole **58b** of the high-pressure turbine **53** is opened, a bypass path extending from the exhaust manifold **4** to the low-pressure turbine **55** is formed. Thus, only the high-pressure exhaust gas tube **59** which allows the high-pressure turbine **53** and the low-pressure turbine **55** to communicate with each other needs to be arranged. Piping for bypassing purpose that allows the exhaust manifold **4** and the low-pressure turbine **55** to communicate with each other needs not be arranged. This can simplify a piping structure in the two-stage turbocharger **30**, and also can provide a large space around the two-stage turbocharger **30**. It therefore is possible that, for example, an oil pressure pump (not shown) for a work machine and the engine starting starter **20** are disposed one above the other at a location below the front side of the two-stage turbocharger **30**.

In the high-pressure turbocharger **51**, a high-pressure working fluid supply pipe **73** and a high-pressure working fluid return pipe **74** are coupled to upper and lower portions of a center housing **72** which is a coupling portion where the high-pressure turbine **53** and the high-pressure compressor **54** are coupled to each other. Likewise, in the low-pressure turbocharger **52**, a low-pressure working fluid supply pipe **76** and a low-pressure working fluid return pipe **77** are coupled to upper and lower portions of a center housing **75** which is a coupling portion where the low-pressure turbine **55** and the low-pressure compressor **56** are coupled to each other.

The high-pressure working fluid supply pipe **73** has its lower end connected to a coupling member **78** disposed on the left surface of the cylinder block **6**, and its upper end coupled to an upper surface of the center housing **72** of the high-pressure turbocharger **51**. A coupling joint **79** is disposed on the upper surface of the center housing **72** of the high-pressure turbocharger **51**, the coupling joint **79** allowing the upper end of high-pressure working fluid supply pipe **73** to communicate with a lower end of the low-pressure working fluid supply pipe **76**. An upper end of the low-pressure working fluid supply pipe **76** is coupled to an upper

surface of the center housing 75 of the low-pressure turbocharger 52. With this configuration, a working fluid flowing in an oil passage within the cylinder block 6 is supplied to the center housing 72 of the high-pressure turbocharger 51 through the high-pressure working fluid supply pipe 73, and is supplied to the center housing 75 of the low-pressure turbocharger 52 through the high-pressure working fluid supply pipe 73 and the low-pressure working fluid supply pipe 76.

The high-pressure working fluid supply pipe 73 is laid between the high-pressure turbocharger 51 and the cylinder head 2 as well as the cylinder block 6 while detouring at the rear of the exhaust gas outlet 44 of the exhaust manifold 4. The low-pressure working fluid supply pipe 76 is laid in an L-shape extending along the upper surface of the high-pressure turbocharger 51 and the center housing 75 of the low-pressure turbocharger 52. Such a piping layout surrounding the two-stage turbocharger 30 which is a high-rigidity component with the working fluid supply pipes 73, 76 shortened enables the working fluid to be efficiently supplied to the two-stage turbocharger 30 and simultaneously prevents the working fluid supply pipes 73, 76 from being damaged by an external force.

The high-pressure working fluid return pipe 74 has one end (lower end) thereof coupled to the distal end (left-side distal end) of a coupling joint 80 disposed on the left surface of the cylinder block 6, and the other end (upper end) thereof coupled to a lower surface of the center housing 72 of the high-pressure turbocharger 51. The low-pressure working fluid return pipe 77 has one end (lower end) thereof coupled to one of branching upper ends of the coupling joint 80, and the other end (upper end) thereof coupled to a lower surface of the center housing 75 of the low-pressure turbocharger 52. With this configuration, a working fluid in the high-pressure turbocharger 51 and a working fluid in the low-pressure turbocharger 52 flow through the low-pressure working fluid return pipes 74, 77 disposed below the center housings 72, 75, to be merged at the coupling joint 80. A merged flow is returned to the oil passage within the cylinder block 6.

The high-pressure working fluid return pipe 74 is laid so as to detour at the rear of the exhaust gas outlet 44 of the exhaust manifold 4. The low-pressure working fluid return pipe 77 is laid between the high-pressure turbocharger 51 and the cylinder head 2 as well as the cylinder block 6 while detouring at the front of the exhaust gas outlet 44 of the exhaust manifold 4. Such a piping layout surrounding the two-stage turbocharger 30 which is a high-rigidity component with the working fluid return pipes 74, 77 shorted enables the working fluid to be efficiently supplied to the two-stage turbocharger 30 and simultaneously prevents the working fluid return pipes 74, 77 from being damaged by an external force.

Configurations of the coolant pump 21 and the coolant inlet pipe 22 will now be described with reference to FIG. 28, FIG. 29, and the like. As shown in FIG. 28, FIG. 29, and the like, a coolant pump attaching part 319 and an inlet pipe attachment pedestal 320 are provided so as to protrude from a portion of the left surface of the cylinder block 6, the portion being relatively close to the rear surface of the cylinder block 6. To the coolant pump attaching part 319, the coolant pump 21 (see FIG. 2, etc.) is attached. To the inlet pipe attachment pedestal 320, the coolant inlet pipe 22 (see FIG. 3, etc.) is attached. The coolant pump attaching part 319 and the inlet pipe attachment pedestal 320 are formed integrally with the cylinder block 6. A portion of the inlet pipe attachment pedestal 320 close to the rear surface is

coupled to the coolant pump attaching part 319. The coolant pump attaching part 319 and the inlet pipe attachment pedestal 320 protrude in a direction away from the crankshaft 5, and can enhance the rigidity, the strength, and the cooling efficiency of the cylinder block 6.

The coolant pump 21 for circulating a coolant is fastened to the rear surface 312 of the cylinder block 6 and to the coolant pump attaching part 319 with bolts. The coolant pump 21 is roughly divided into a base plate portion 331, a cover plate portion 332, and a pumping pulley 333.

The base plate portion 331 and the cover plate portion 332 have their peripheral edge portions fixed in tight contact with each other by covering bolts 347 that are inserted and fastened, from the cover plate portion 332 side, into five bolting through holes disposed in the peripheral edge portion of the base plate portion 331 and into through holes of the cover plate portion 332 corresponding to the bolting through holes.

The coolant pump 21 is bolt-fastened to the cylinder block 6 such that the plate portions 331, 332 are clamped together by mounting bolts 348 that are inserted in nine through holes disposed in each of the peripheral edge portions of the base plate portion 331 and the cover plate portion 332. Clamping with the mounting bolts 348 causes the peripheral edge portions of the base plate portion 331 and the cover plate portion 332 to be fixed in tight contact with each other, also causes a portion of the cylinder block 6 surrounding a coolant passage outlet 327 and a portion of the coolant pump 21 surrounding a pump suction port 334 to be fixed in tight contact with each other, and further causes a portion of the cylinder block 6 surrounding a coolant inlet port 328 and a portion of the coolant pump 21 surrounding a pump ejection port 335 to be fixed in tight contact with each other. As for arrangement of the bolts 347, 348 along the peripheral edge portion of the coolant pump 21, one or two mounting bolts 348 are disposed between adjacent ones of the covering bolts 347, 347.

Since the base plate portion 331 and the cover plate portion 332 are coupled to each other with the covering bolts 347, the coolant pump 21 can be distributed as a single component, and moreover an attaching work in mounting the coolant pump 21 to the cylinder block 6 with the mounting bolts 348 is easy.

The base plate portion 331, for example, includes a pump suction port 334 and a pump ejection port 335, the pump suction port 334 being connected to the coolant passage outlet 327 which includes a portion of the coolant pump attaching part 319 and which is opened in a relatively left portion of the rear surface of the cylinder block 6, the pump ejection port 335 being connected to the coolant inlet port 328 which is opened in a relatively right portion of the rear surface of the cylinder block 6.

The base plate portion 331 and the cover plate portion 332 have their peripheral edge portions in tight contact with each other, to form an in-pump coolant passage 336 that connects the pump suction port 334 to the pump ejection port 335. An annular seal member that surrounds the pump suction port 334, the pump ejection port 335, and the in-pump coolant passage 336 is disposed in a portion where the base plate portion 331 and the cover plate portion 332 are in tight contact with each other. The cover plate portion 332 pivotally supports a pump shaft 337 in a rotatable manner. An impeller is secured to one end portion of the pump shaft 337. The pumping pulley 333 is secured to the other end portion of the pump shaft 337.

A coolant passage inlet 329 is opened in the left surface of the cylinder block 6. The coolant passage inlet 329 is

opened in the inlet pipe attachment pedestal **320** which protrudes from the left surface. An in-block coolant passage **338** (coolant passage) is formed inside the cylinder block **6**. The in-block coolant passage **338** has a substantially L-shape that connects the coolant passage inlet **329** opened in the left surface to the coolant passage outlet **327** opened in the rear surface.

The inlet pipe attachment pedestal **320** has a pair of bolt holes on opposite sides of the coolant passage inlet **329**. The coolant inlet pipe **22** (coolant inlet member) having a coolant inlet **339** is detachably fastened to the inlet pipe attachment pedestal **320** with bolts. Piping leading to the coolant outlet of the radiator is connected to the coolant inlet pipe **22**. A coolant coming from the radiator is introduced into the engine **1** through the coolant inlet pipe **22**, flows through the in-block coolant passage **338** and the coolant pump **21**, and then taken into the cylinder block **6** from the coolant inlet port **328**.

In the engine **1** of this embodiment, the coolant inlet pipe **22** having the coolant inlet **339** is detachably attached to the coolant passage inlet **329** which leads to the pump suction port **334** of the coolant pump **21**. Accordingly, the position of the coolant inlet **339** can be changed just by changing the shape or the like of the coolant inlet pipe **22**. This enables the position of the coolant inlet **339** of the coolant pump **21** to be easily changed without any major design change or any increase in manufacturing costs.

The coolant passage outlet **327** that supplies a coolant from the radiator to the coolant pump **21** is disposed on one of the left and right sides of the cylinder block **6**, while the coolant inlet port **328** that takes a coolant from the coolant pump **21** into the cylinder block **6** is disposed on the other of the left and right sides of the cylinder block **6**. The in-pump coolant passage **336** that connects the coolant passage outlet **327** to the coolant inlet port **328** is disposed across a portion close to the left surface of the cylinder block **6** and a portion close to the right surface of the cylinder block **6**. With this configuration, a coolant passing through the in-pump coolant passage **336** is cooled by cooling air supplied from the cooling fan **9** (see FIG. 2) while the coolant is moving from the coolant passage outlet **327** to the coolant inlet port **328**. The coolant can be cooled within the coolant pump **21** before being taken into the cylinder block **6** from the coolant inlet port **328**. Accordingly, the cooling efficiency of the engine **1** can be enhanced.

The configurations of respective parts of the present invention are not limited to those of the illustrated embodiment, but can be variously changed without departing from the gist of the invention.

REFERENCE SIGNS LIST

1 engine
2 cylinder head
3 intake manifold
4 exhaust manifold
5 crankshaft
6 cylinder block
7 flywheel housing
8 flywheel
9 cooling fan
51 high-pressure turbocharger
52 low-pressure turbocharger
53 high-pressure turbine
54 high-pressure compressor
55 low-pressure turbine
56 low-pressure compressor

57 exhaust gas inlet
58 exhaust gas outlet
58a turbine discharge hole
58b bypass hole
59 high-pressure exhaust gas tube
60 exhaust gas inlet
61 exhaust gas outlet
62 air supply pipe
63 fresh air inlet port
64 fresh air supply port
65 low-pressure fresh air passage pipe
65a metal pipe
65b resin pipe
66 fresh air inlet port
67 fresh air supply port
68 recirculation hose
69 wastegate valve
70 blow-by gas outlet
71 high-pressure fresh air passage pipe
72 center housing
73 high-pressure working fluid supply pipe
74 high-pressure working fluid return pipe
75 center housing
76 low-pressure working fluid supply pipe
77 low-pressure working fluid return pipe
78 coupling member
79 coupling joint
80 coupling joint

The invention claimed is:

1. An engine device comprising:

an exhaust manifold;
 an intake manifold arranged in a cylinder head; and
 a turbocharger for compressing fresh air to be introduced into the intake manifold by fluid energy of exhaust gas discharged from the exhaust manifold,
 wherein the turbocharger comprises a two-stage turbocharger including a high-pressure turbocharger provided on the exhaust side of the cylinder head and a low-pressure turbocharger communicating with the high-pressure turbocharger, the high-pressure turbocharger includes a high-pressure compressor and the low-pressure turbocharger includes a low-pressure compressor, and a fresh air outlet of the low-pressure compressor of the low-pressure turbocharger and a fresh air inlet of the high-pressure compressor of the high-pressure turbocharger open in the same direction and communicate with each other through a fresh air relay pipe, the high-pressure turbocharger is disposed laterally from the exhaust manifold, and the low-pressure turbocharger is disposed above the exhaust manifold, such that the two-stage turbocharger is flanked close to a lateral surface and an upper surface of the exhaust manifold.

2. The engine device according to claim **1**, wherein the low-pressure compressor has a fresh air inlet that opens laterally with respect to the low-pressure compressor, and the fresh air outlet that opens laterally with respect to the low-pressure compressor after being protruded away from the low-pressure compressor.

3. The engine device according to claim **1**, wherein the fresh air relay pipe is U-shaped.

4. The engine device according to claim **1**, wherein the high-pressure turbocharger further includes a high-pressure turbine, and the low-pressure compressor is disposed above the high-pressure turbine of the high-pressure turbocharger.

5. The engine device according to claim 4,
wherein the low-pressure turbocharger further includes a
low-pressure turbine, the high-pressure turbine has an
exhaust inlet opening toward the exhaust manifold and
an exhaust outlet opening toward the low-pressure 5
turbine, and
the low-pressure turbine opens with an exhaust inlet
facing downward, and
wherein the exhaust outlet of the high-pressure turbine
and the exhaust inlet of the low-pressure turbine com- 10
municate with each other via an exhaust relay pipe.
6. The engine device according to claim 5, wherein the
exhaust relay pipe is L-shaped.

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